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OF ENGLAND

THE FARMER'S GUIDE

TO AGRICULTURAL RESEARCH IN 1931

Practice with Science

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NOTE

This volume continues the series of annual summaries of Agricultural Research in its leading branches, issued by the Royal Agricultural Society of England under the direction of its Research Committee, though it appears under a new title. It was always the purpose of the Society to use the publication as a means of spreading the lessons of research amongst those to whom they are likely to be of greatest use, and to give the farmer information on the results of the year's work in a summarised and simple form.

To give emphasis to this object, the title of the work has been changed from *Agricultural Research* to *The Farmer's Guide to Agricultural Research,* and some of the titles of the subjects treated in the volume have been varied to conform to this purpose also.

In other respects, the form of the publication is unchanged. The survey of scientific work which it provides is not limited to research in this country, but includes references to work in any part of the world which may throw light upon the problems of British Agriculture.

The volume is available to members of the Society free on application to the Secretary, and at a nominal charge to the general public. The Research Committee is desirous that the information it contains should be drawn upon freely by agricultural lecturers, organisers, and by the Press, so that it may receive the widest publicity.

This volume is the seventh of the series. The only changes to be noted in its contents are that the section on "Crops and Plant Breeding" is temporarily suspended, and that a new section on "Pests and Parasites," by Mr. J. C. F. Fryer, is included. The section on "Farm Economics" is contributed this year, by Professor A. W. Ashby.

A few copies of previous issues, those for the years 1925–1930 are still available.

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DAIRY FARMING AND DAIRY WORK.

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I.—Dairy Herd Management.

The management of a dairy herd and the production of milk are essential features of the business of dairy farming, and must receive careful attention if the business is to be conducted in a profitable manner. To a considerable proportion of herd owners, however, the purely business aspect of herd management is made more interesting, and it may be something of a hobby, by attempting to maintain and improve the herd by breeding. To those who have this additional interest in life there are few things more pleasing than the inspection of a herd of cows in the field, in company with the owner or manager who can describe the type of cow he is trying to breed, amplifying his description by pointing to individual animals, and who also can give the family history, in terms of milk yield as well as ancestry, of the different members of the herd as they are met with ; daughters and grand-daughters are compared with their dams ; half-sisters are grouped and the good points and defects introduced by different sires are commented on, and, if the herd has been chiefly maintained by home-bred stock for a considerable period, the tendency to increase a number of families and to dispose of others forms a fruitful topic of discussion.

In every county there are numerous farms where the breeding of the dairy herd is the hobby as well as the business of the owner, but it very rarely happens that an attempt is made to compile a written history of the herd for the information and guidance of others; indeed, a combination of practical knowledge and an ability to use the figures which accumulate in years of milk recording is essential, hence it is probably easier to prepare such a history of an agricultural college herd than of one kept under ordinary farm conditions.

At the farm of the University of Reading a herd of Dairy Shorthorns has been maintained since 1908 under the same management, and the history which has been written by Pennington and Campbell (Ref. 1) contains much information of great interest and value to the breeder and student. It is stated that the aims in the building up of the herd were (1) to grade up for registration in Coates' herd book; (2) to breed a type of animal with (*a*) good milking ability as a first essential, (*b*) ability to produce milk of high fat content, (*c*) a constitution capable of a long milking life, and (*d*) a frame to carry and the power to lay on flesh—the so-called dual purpose type of Dairy Shorthorn; (3) to make it self-supporting and independent of bought stock as soon as possible; (4) to establish a herd free from tuberculosis.

These aims are those of numerous farmers and as the University herd has been managed as an ordinary good commercial herd, the methods followed and the degree of success achieved cannot fail to be of interest. The grading up of the herd for registration in Coates' herd book is a slow process and the rate of progress is largely dependent on the proportion of heifer calves born; of the 43 cows and heifers in the herd in 1931, all are entered with the exception of 3 class D cows retained for breeding on account of their good records, and 3 class D heifers; about 22 years have therefore been required for the attainment of this end. The degree of success attained in breeding for milk is shown by full statements of the milk records of each cow for each year and lactation period, and the annual average milk yield as calculated by the Berkshire Milk Recording Society. The average annual yield for the 22 years is 7,998½ lb. for 12 full year cows. The length of life of the cows is naturally governed by their health, productivity and the supply of young stock available for herd maintenance; it is stated that the average milking life in this herd of 64 home-bred cows was 3·31 lactations, but a number of these cows which were sold are known to have continued milking and breeding satisfactorily in other herds. The type of cow which gradually became representative of the herd is indicated by a tabulated statement of successes in herd competitions; this

list shows that in open and county competitions the first and second place was frequently gained—an evidence of the possession of good cows. The maintenance of the herd by home-bred females was possible after 1911 ; up to that year it had been necessary to purchase heifers in calf or newly calved, but since 1911 no purchase of cows or heifers has been made and from time to time a number of surplus heifers and cows have been sold. The efforts to establish a tubercle-free herd have also been very successful. During the first four years 15 animals reacted, but after 1912 the herd remained free until 1918, when one animal reacted ; from 1918 to 1928 there were no reactors, but in the latter year several animals reacted and were at once disposed of ; from the time of this outbreak to 1931 there have been no further reactors. In 1925 a case of contagious abortion occurred ; following this case all cows and heifers were inoculated eight weeks before service with the living culture ; since January, 1927, there have been no further cases.

The general system of feeding and management followed is also described, and a list of the stock bulls used with the extended pedigree of each and the main features of their progeny are also given. The milk yields of each cow are also tabulated, firstly as members of the particular family on the female side, and secondly as the progeny of the respective bulls. The milk yields are given in terms of the actual lactation yields and also as the " standardised " yield in order to facilitate comparisons between dams and daughters, progeny groups, etc. The fact that *all* the animals bought, *all* the calves born and *all* the heifers which entered the milking herd are included in the published records, adds to value of this history of the development of a dairy herd, and farmers interested in this subject will find the bulletin well worthy of careful study.

Causes of Removal of Cows from Herds.

The publicity given to this subject in recent years has led to investigations as to the main causes of removal in different parts of the country. The Dairy Husbandry Department of the National Institute for Research in Dairying has issued an interim report (Ref. 2) on an investigation in the counties of Berks, Dorset and Hants, and the Hannah Dairy Research Institute has also published a report (Ref. 3) giving the preliminary conclusions derived from a similar inquiry amongst typical dairy herds in Scotland. The results from the area in the south of England are derived from 322 herds containing 9,478 cows and those obtained in Scotland from 490 milk recorded herds. Owing to the difficulty in obtaining really reliable information from such a large number of herds during the first year of investigations of this nature, only tentative

conclusions are given, but both reports agree that sterility in some form or other is one of the chief causes of removal and wastage.

II.—Dairy Cattle—Type, Breeding and Management.

The Inheritance of Milking Qualities.

The problems associated with the inheritance of milking qualities in dairy stock and the relative influence of the individual parents and grand-parents continue to receive close attention and the amount of reliable information on this subject, though still very limited, continues to increase.

The suggestion that sex linkage plays a part in the transmission of milking qualities is based on statistical calculations of the amount contributed by the parents and grand-parents to the milk and fat-producing power of any animal. Such calculations have, in several instances, shown that the paternal grandsire apparently has contributed less than the other grandparents, and, as one form of sex linkage would have this result, it has been suggested that some of the milk-yielding qualities may be inherited in a sex-linked manner (Ref. 4). If it were proved beyond question that the milk yielding qualities (or lack of them) possessed by a particular bull could be passed on to his daughters but not to his sons, a basic fact of great importance in breeding would have been established. For example, in the study of pedigrees in so far as milk yields are concerned, no attention would need to be given to the paternal grandsire—if the paternal grand-dam and the maternal grandsire and grand-dam were of really good milk breeding all would be well. If this policy could be applied to the breeding of Dairy Shorthorns it would mean that the sons of a " beef-bred " bull out of a good milking cow could be used in dairy herds without the risk of lowering the milking qualities of the progeny. In view of the importance to the dairy farmer of maintaining the milking qualities of his herd it is obviously essential that no such practice should be advocated until the fact of sex-linkage has been definitely proved. This stage has not yet been reached.

Buchanan Smith and Robison (Ref. 5), using data obtained from Ayrshire herds in the south-west of Scotland, have studied this question by a different method from that of the proportionate inheritance from each grand-parent, and have been unable to arrive at a definite conclusion—they state that the point to be emphasised is that it is not unreasonable to assume that a few of the factors affecting the inheritance of milk yield may be transmitted in a sex-linked manner and that no evidence has been obtained which tends to disprove this hypothesis. It may be suggested that at this stage of our

knowledge of this subject the lack of evidence in favour of the theory is more to be emphasised than the absence of disproof. Joyce (Ref. 6) in a pedigree study of high-yielding Ayrshires carried out in Canada, also studied sex-linkage in another manner. The descendants of a number of bulls renowned as sires of high producing stock were studied, particularly those which had the bull in question as paternal grand-sire, and the conclusion was arrived at that in the transmission of milking qualities the paternal grandsire was as important as any of the grandparents and that sex-linked factors do not play an important part in the inheritance of milk yield.

The "Proving" of Sires.

During recent years much attention has been given to the problem of judging the dairy value of a bull by the production records of his progeny, in addition to the milk records and appearance of his ancestors and his own breed points, and previous issues of *Agricultural Research* have contained summaries of many investigations on this subject. The progeny test, in the sense that the milk or fat records of the daughters of a particular bull are good, medium or poor and are used as an indication of the bull's value, is easily understood, but when attempts are made to express the results of the progeny test in terms of figures the position becomes more complicated, and care must be taken that the figures are reliable and are interpreted fairly.

The Report on the International Dairy Congress, 1931, contains a paper by Gowen (Ref. 7) which gives an analysis of the available means of estimating a bull's breeding potentialities in terms of milk and fat yields. No less than five methods are given and, in view of the fundamental importance of sound judgment in the selection of bulls, the four most frequently used will be briefly summarised.

1. The first method is based on the yield of the daughters and has the merits of being the simplest, the most easily obtained and of definitely indicating the production of the daughters, but it does not take account of the productive power of the dams. Usually the yield of the daughters is calculated to the estimated yield at maturity by means of age-correction factors, and in this way allowance is made for daughters calving at different ages.

2. The second method is based on a comparison of the daughters' yields with their dams' yields. It is of most value to the owner of the bull because, if the yield of the daughters is superior to that of their dams, the bull in question is improving the herd, whereas if the yield of the daughters is inferior, the

bull is exercising a harmful effect. It will be obvious, nevertheless, that a bull which, when mated with good cows, begets daughters as good as their dams, is in fact a good bull even though the daughters show no improvement, hence, if the value of the bull is judged merely by the difference between the yields of daughters and dams, a true indication of the bull's value will not be obtained.

3. The third method attempts to take into account the average production of the breed to which parents and progeny belong, the number of dams and daughters and the age-corrected yields of both ; it is probably as accurate as any other method but it is too complicated for general use.

4. The fourth method (usually known as the Mount Hope method (Ref. 8)) is based on the results obtained in cross-breeding experiments between a high-producing and a low-producing breed, and on the belief that what was found in crosses between breeds might also be found in matings within a breed. It assumes that the daughters' milk yields are 7/10 and their fat percentages 4/10 above that of the lower parent. This method has the advantage of stating the apparent inheritance of fat in addition to that of milk. Owing to vigorous advertisement it has received considerable attention and is reported to have been adopted by the Royal Guernsey Agricultural Society (Ref. 9) and others. It is, however, more difficult to apply in practice, and there is a lack of evidence that it is safe to assume that milk yield and fat percentage are inherited in the proportions stated above. Further, the calculation of the index is based on the difference between the yields of the daughters and their dams, and as pointed out above, this method alone does not give a true measure of the bull's value. A writer in Hoard's Dairyman (Ref. 10) in discussing the Mount Hope method, emphasises the importance of considering the dams' and daughters' records in relation to standard of the breed and points out that to describe a bull as poor, whose daughters have yields above average for their breed, even though somewhat below the yields of their dams, would condemn many valuable bulls and retain poorer ones. It is also interesting to note that this index system has not yet earned the approval of the American Guernsey Cattle Club. (Ref. 11).

The reliability of the methods outlined above has been computed by Gowen, and he concludes that the first method, *viz.* the average age-corrected yields of a group of daughters, is as accurate as any and that it is the best adapted to common use as it is the simplest to calculate. Gifford (Ref. 12) has also compared the different methods of stating the dairy breeding ability of bulls, and comes to the same conclusion as Gowen.

He states that the average of all the sires' daughters is of more practical value in evaluating sires than any of the methods suggested up to date.

When referring to American work on the study of bull indices and related subjects, it is necessary to point out that the data as to milk and fat records of dams and daughters have usually been obtained from the Advanced Register records of the chief Breed Societies. The minimum entrance requirements for each register are fairly high, hence the poorer yielders which never qualify for entrance, and the poorer records of those which do qualify, are not to be found in such registers; in other words, the data obtainable from Advanced Registers is selected on the basis of good yields and does not fairly represent the range of production of the different breeds. This weakness has been recognised by Gifford.

The value of progeny records in the selection of bulls has been recognised for many years in Denmark and Holland. In Denmark, Larsen (Ref. 13) states that progeny performance tests are worked out for 300 to 400 bulls annually, through the agency of the state-aided cow testing associations. The Danish basis on which the breeding value of bulls is calculated is simply the comparison of the average yield of the daughters of a certain bull, with the yields in the corresponding years of their dams, *i.e.* the yield of a heifer is compared with that of her dam when she was a heifer. Larsen adds that the fact that about 39 per cent. of all Danish milk cattle are officially tested by such associations makes it possible, in most cases, to include in the test all the female offspring from a bull. Comprehensive and practically unselected data such as this are undoubtedly more reliable for the purpose of calculating bull indices than that taken from Advanced Registers only.

Number of Daughters Necessary.

After the method of measuring the bull's breeding value by means of progeny records has been agreed on, it is then necessary to decide *how many daughters' records* are required in order to obtain a reliable indication or index. In this connection Gowen has attempted to show (Ref.7) that where the sire is continued in the same herd, the milk yields of two daughters are as reliable as the milk yields of ten for estimating the bull's value. No other study of the subject supports such a statement and it appears that Gowen has been misled by the use of Advanced Registry data. On this subject, Gifford (Ref. 12) states that the value to be placed upon the bull index is greatly influenced by the number of daughters tested; he suggests that six daughters' records may be considered the minimum

number and that a slightly larger number is desirable. In the Danish progeny performance tests referred to above an average of six daughters is usually considered insufficient to afford a sound basis as later results often differ somewhat; nine to ten daughters should be the minimum, although in order to gain information sooner, six are sometimes used. Lush (Ref. 14) has also studied this subject and points out that, in addition to the qualities which the progeny derive from their sire, the qualities inherited from the dams and the conditions of management in the herd containing the progeny also exercise an effect on the daughter's yields. Where management is uniformly good a reliable indication will be obtained from a smaller number of daughters than with varied conditions of management. He suggests that if a definite number of daughters must be adopted to "prove" a sire, perhaps five is as practical as any other, and he also points out that, from the principles underlying the progeny test, we will occasionally meet with cases where a sire "proved" to be good in one herd will be "proved" bad in another, and that some sires will be proved to be poor ones merely because of chance variations or because they were used in herds where the daughters did not receive adequate care and management.

In the United States several schemes have been inaugurated to discover proved sires and in the Massachusetts State scheme (Ref. 15) the records of six or more daughters from at least three different dams are required; also each member must agree to test all the daughters of a given sire in his herd. In the Vermont scheme (Ref. 16) the records of five or more dam-daughter pairs, or sixteen or more records from eight or more daughters are required and also the records of all daughters of the sire must be reported. It is essential to the success of all such schemes that the breeding value of the bull be judged by the records of unselected daughters, and as this information is wanted at the earliest possible moment it would appear reasonable to suggest that the records of the first six daughters in order of calving be used for this purpose. Experience may show that in dual-purpose breeds a larger number is required than in dairy breeds to give a reliable indication of the bull's breeding value for milk production.

Management of Old Bulls.

In dairy herds the value of a bull by the progeny test cannot be ascertained until the bull is approximately five years old, and as the keeping of a bull until this age often involves problems of management, information on this subject is welcome. A bulletin issued by the Connecticut Agricultural College (Ref. 17) gives useful advice on many points. The importance of

exercise in maintaining health, vigour, fertility and good temper is stressed, and it is suggested that if the bull is usually housed indoors an exercise yard should be provided with easy access from the bull pen ; a long narrow yard (say 20 x 60 to 80 feet) will provide more exercise than a square one of the same area, and if the ground is not well drained, a gravel or cinder surface may be necessary. The exercise yard or paddock should be located so that the bull can look into the fields or yards where the cows are kept ; this arrangement tends to keep a bull in a better temper. For bulls of uncertain disposition a breeding rack should be erected adjacent to and with access from the yard. Plans and sketches with dimensions are included in this bulletin. Another useful suggestion is that young bulls should be trained to have their feet handled so that the trimming of the hoofs may be more easily carried out in later years.

III.—Secretion of Milk and Milking.

Milking Before Calving.

A group of workers at the Missouri Agricultural Experiment Station are carrying out a detailed study of the growth and development of the mammary gland and a bulletin recently issued (Ref. 18) deals with the development of this gland as measured by the presence and increase of fluid secreted in the udder from birth onwards. In addition to the technical description and the discussions of the results obtained, the question whether cows should be milked before calving is considered, and it is stated that from the point of view of the well-being and comfort of the cow the practice of milking for a period of about ten days prior to parturition has certain advantages. The inflammation of the udder which occurs at this time can be prevented by the removal of milk and, where this practice was followed, it was noted in both first-calf heifers and cows that the udders at calving were soft and pliable and not painful. It is also suggested that the bringing of cows gradually into lactation by milking before calving would have a tendency to reduce the risk of milk fever. From the standpoint of the well-being of the calf, however, milking the dam before calving is not so satisfactory. One result of such milking is that by the time of calving, the milk has ceased to be of the nature of colostrum, and the lack of colostrum for the newly born calf increases the risk of ill-health and death. Out of seven calves born from seven cows and heifers milked for ten days before calving, two died within ten days of birth and one when ten weeks old ; in each of these cases there was definite evidence of internal *bacillus coli* infection.

Frequency and Regularity of Milking.

The results of milking cows three times daily and of irregularity in milking and feeding are often discussed by dairy farmers, and some useful additional information on these subjects is given by Woodward (Ref. 19). Four cows similar in every respect and receiving the same quantities of food were milked twice and thrice daily in alternate periods of 40 days throughout a lactation period ; the results showed an increased production for the thrice milking periods of about 11 per cent. milk and 10 per cent. fat, and at every change from twice daily to thrice daily milking there was an immediate increase in production, and when changed from thrice daily to twice daily there was an immediate decrease. Another experiment on the same subject was carried on throughout successive lactation periods in order to obtain a measure of the effect of thrice daily milking over a long period. In this experiment eight Holstein cows were used, and the increase as a result of milking thrice daily varied greatly for different cows, ranging from 7.8 per cent. to 42.8 per cent., with an average increase of 20 per cent. for milk and 21 per cent. for weight of fat over periods of seven to twelve months. The long-period experiment therefore, showed increases approximately twice those obtained in the short-period experiment and these increases are attributed mainly to a greater persistency in milk yield.

The above-mentioned experiments also shed some light on an aspect of thrice-daily milking, which is of interest to many British farmers, *viz.* the effect on the yield and percentage of fat. It is shown that milking three times daily increases the yield of milk and of fat to practically the same extent, hence the fat percentage in the milk is not affected. This can be illustrated from the long-period experiment ; the average fat percentage for the eight cows throughout the lactations in which they were milked thrice daily was 3.57 per cent., whereas the average for the lactations in which they were milked twice was 3.54 per cent. A similar result was obtained in the short-period experiment. It has been noted by several farmers in this country that cows milked thrice daily at equal intervals give very uniform yields at each milking, but there is a marked variation in the fat percentages, the morning yield containing least fat, and the afternoon yield containing most, with the evening fat content approximating to that of the afternoon. The same results have been noted at the London Dairy Show (Ref. 20), but unfortunately the American experiments do not deal with this aspect of the question.

Experiments were also carried out to obtain information on the effect of changing milkers, and on milking and feeding at irregular hours. In the former, three good milkers each milked

the same group of cows for a 30-day period ; during the next 30-day period no cow was milked twice in succession by the same man, and in a third 30-day period each milker again milked the same cows. The records of milk yield and fat yield showed that the changing of milkers had practically no influence and it is suggested that when cows were accustomed to having different men to care for them, milking by a different milker will result in no material decrease in production, provided all milkers are equally efficient. In the experiment wherein milking and feeding at regular hours was compared with milking and feeding at irregular hours, it was found that in the regular period the cows produced on the average 3·90 per cent. more milk and 5·25 per cent. more butter fat than in the irregular period. Campbell (Ref. 21) has also studied the possible influence of the milker on the quantity and quality of the milk yielded by individual cows and found appreciable differences in yield of milk and fat when the milkers were changed. When one good milker milked a group of cows at each of the thrice-daily milkings over a period of two weeks, distinctly better results were obtained than when the three daily milkings were carried out by two milkers. The increase in yield and fat obtained may have been due to the fact that only one milker was employed, or that this one milker was more efficient than the other two. A survey of the available information shows that under English conditions milking thrice daily at equal or nearly equal intervals does not overcome the difficulty of low fat content of the morning's milk, and that frequent changes of the milkers may intensify this difficulty.

Mechanical Milking.

The interest of dairy farmers in mechanical milking continues to increase, and there appears good reason to believe that the types of machines installed and the methods of management and cleansing advocated during recent years give greater satisfaction than formerly. Improvements have no doubt been devised and incorporated into practice by manufacturers and others, but the official testing of milking machines and the publication of certificates and reports of performances under test by the Agricultural Machinery Testing Committee of the Ministry of Agriculture have undoubtedly contributed to the reliability and efficiency, not only of the mechanical parts and action, but also to the methods of management and cleansing.

The first report of the above-mentioned committee (Ref. 22) contains details of the tests of two milking machines, and it is pointed out that the test in each case covered at least a full lactation period of several cows and that the efficiency of the

machine was compared with first-class hand-milking. Further, the methods of washing and cleansing recommended by the maker were tested, and the effects of those methods noted on the materials used in the construction of the milking unit, and on the bacteriological content and keeping qualities of the milk obtained by the machine. The report[1] gives full details of the test of each machine and is well worth study by farmers using or proposing to use a mechanical milker. The conclusions from both tests are briefly summarised as follows :—(1) the machine worked satisfactorily from the mechanical point of view, and there was no indication that any parts were subject to undue wear ; (2) the milking parts were easy to disassemble and to clean ; (3) the machine had no injurious effects on the cows and led to no depression of milk yields ; (4) the rate of milking was equal to that of first-class hand-milking ; (5) from the point of view of hygiene the machine gave excellent results provided that the units were thoroughly washed and then sterilised by steam. Further information on the management of milking machines can be obtained in Bulletin 31—" Studies concerning the handling of milk "—issued by the Ministry of Agriculture.

An interesting report on the use of a milking machine is given by Phillips and Thomas (Ref. 23) based on two years' experience at the University College Farm, Aberystwyth. It is stated that " most cows seem to prefer the machine to the ordinary hand milkers. The gentleness with which the mechanical milker operates has a calming effect upon the cow. This influence is also noticeable with nervous cows as well as with individuals suffering from sore teats and other superficial udder troubles, cuts, abrasions, etc.. . . . Heifers with small teats, which are troublesome to milk by hand, are satisfactorily milked by machine, and provided the teat cup liners are tight there is no danger of the teat cup falling off." Details are also given of sundry costs :—Replacements (mainly teat cup liners), £5 5*s*. 6*d*. per annum ; petrol, oil, etc., £18 per annum ; depreciation and interest on capital, £17 10*s*. per annum ; and labour and cleansing, £5 17*s*. per annum. The total cost for the first two years of operation was 18*s*. per week, but these figures are of little value owing to the omission to state the number of units in use, and the average number of cows milked. The bacteriological condition of the milk was also studied. The foremilk, mid-milk and strippings of a number of cows was examined, and the average counts were 4,605 per c.c., 1,329 per c.c., and 662 per c.c. respectively. The results show that

[1] This report also contains particulars of the tests of other agricultural and dairying implements and apparatus carried out for the committee.

the bacterial content of the foremilk is about eight times that of the strippings, and that the discarding of a few squirts of foremilk is justifiable. When samples obtained by machine and by hand were compared, it was found that the bacterial counts for the machine milk samples taken as a whole were quite as low as those of the hand milked samples, and that the test for coliform organisms gave equally favourable results; fully 80 per cent. of all the samples contained less than 100,000 bacteria per c.c. and coli present in 1/10 c.c. or less.

IV.—Composition of Milk.

Causes of Variation in Yield and Quality.

The circumstances which influence the composition of milk, such as breed of cow, stage of lactation, efficiency of milker, etc., are known to most dairy farmers. It is also recognised that when the time interval between milking exceeds 12 hours the percentage of fat is lowered, and when the time interval is less than twelve hours the percentage of fat is increased. Campbell (Ref. 24) criticises the mode of expression of the above fact, which seems to imply that the decrease in fat is due simply to a longer interval, and suggests that it is necessary to consider the factors which may operate during or because of a longer interval, and to attempt to measure the effect of each. As a contribution to a study of this subject he has carried out experiments with six cows milked at hours which gave a 15-hour interval during the day for two to three months, and a 15-hour interval during the night for a subsequent period of two to three months. The results from all the cows showed that a bigger proportion of the twenty-four hours' yield was obtained after a 15-hour night interval (normal conditions on many dairy farms) than after a 15-hour day interval, and that in four out of the six cows a higher fat percentage was found after the long day interval than after the long night interval. Campbell infers from these results that during winter conditions of milk production, night itself, or factors operating at night, tend to high milk production of low fat content, and states that such factors include darkness, quietness, restfulness, temperature and scarcity of water (in some cases); to these may be added accumulation of milk in the udder. A measure of the effect of each of these factors, if this be possible, is now required.

The effect of temperature in general has been studied by Brooks (Ref. 25), using the monthly butter fat percentages of 409 normal lactations of cows in the dairy herd of the Kansas Agricultural Experiment Station during the years 1912 to 1927; the effects of gestation and lactation were eliminated by having as nearly as possible the same number of lactations

beginning each month throughout the year. The average fat percentage for each month was studied in relation to the average temperature of each month, and it was found that as the temperature increased the fat percentage decreased; this conclusion held good for each of the four dairy breeds represented in the station herd. The monthly average temperature and fat percentages are shown in the following table:—

Month	Temperature	Butter Fat	Daily Milk Production	Breed Fat Content			
				Jersey	Guernsey	Ayrshire	Friesian
	°F.	%	lb.	%	%	%	%
Jan.	29·0	4·23	23·5	5·39	4·80	3·96	3·49
Feb.	31·2	4·16	24·5	5·38	4·82	3·87	3·47
March	43·9	4·01	25·3	5·28	4·71	3·81	3·42
April	54·4	4·07	26·3	5·27	4·74	3·76	3·37
May	64·5	4·01	26·9	5·18	4·66	3·72	3·41
June	74·3	3·95	25·7	5·01	4·55	3·67	3·36
July	78·5	3·92	23·7	4·75	4·38	3·66	3·39
August	77·9	3·83	24·9	4·78	4·43	3·63	3·26
Sept.	70·4	4·01	24·7	5·12	4·72	3·75	3·38
Oct.	57·7	4·04	24·2	5·24	4·83	3·75	3·38
Nov.	44·1	4·11	23·8	5·45	4·94	3·87	3·43
Dec.	31·3	4·25	23·0	5·64	4·93	3·94	3·54

The data presented above show clearly the fall in the fat percentage as the temperature rises; the general inference may well be applicable to this country, but as the range of temperature from winter to summer is much less in England than in Kansas, the same marked variation in winter and summer fat percentages cannot be expected in Britain. It may also be pointed out that the association of higher average temperature and lower fat content does not simplify the problem of the effect of night. During night the average temperature is lower than during the day and the high day temperature can only be associated with the lower fat percentage in the morning by assuming a twelve hours' lag—at the moment we do not know whether such an assumption is justified.

Deficiency in Solids-not-Fat.

During recent years instances of samples of milk from individual cows and even of mixed samples from a number of cows, containing less than the presumed standard amount of "solids-not-fat" (8.5 per cent.) have been reported with increasing frequency. When advice is asked by farmers as to how this deficiency may be made good it is exceedingly difficult to give a helpful answer. The percentage of solids-not-fat undoubtedly varies with different breeds, and with individual animals within a breed, but there is no evidence that it is

affected materially by factors operating during long or short milking intervals, nor by changes in feeding. An interesting experiment is reported by Lesser (Ref. 26), in which a herd of Friesian cows known to be yielding milk low in solids-not-fat was divided into three groups; the cows in the first group (control) received throughout the winter the usual ration of the farm, which consisted of 14 lb. seeds hay, 7 lb. oat straw, 30 lb. mangolds, and 3½ lb. concentrates per gallon of milk; the second group received the same ration except that 20 lb. marrow stem kale per head replaced the mangolds; and the third group received the same ration as the control group with the addition of 6 oz. malt and cod liver oil per head daily. Samples from each cow in each group were examined at weekly intervals during the experimental period; the result confirmed the production by this herd of milk naturally low in solids-not-fat, and did not show any advantage accruing from the experimental feeding. The proportion of samples containing less than 8·5 per cent. solids-not-fat from the individual cows in each group was as follows:—Control group, 78·3 per cent.; marrow stem kale group, 82·7 per cent.; malt and cod liver oil group, 79·5 per cent. When the cows in each group were turned out to pasture day and night in May, there were indications that in some cases the percentage of solids-not-fat increased rapidly.

In view of such results it is important that dairy farmers and others concerned with the composition of milk should realise that it is now possible to determine with certainty if a sample of milk contains added water. This is done by ascertaining the freezing point of the sample by means of special apparatus (Ref. 27, 28). It has been found by workers all over the world that genuine milk as it comes from the cow has a freezing point which varies only within very narrow limits, and is in fact the most constant property of milk yet discovered. The limits of variation are from about −0·53° C. to −0·55° C., and genuine milk, whether from a herd or from single cows, or whether it contains more or less than 8·5 per cent. solids-not-fat, never has a freezing point higher (*i.e.* nearer to 0° C.) than the first of these figures. This test when applied to the samples obtained from the herd mentioned above, showed that the milk was genuine milk (as it was known to be), even though some 80 per cent. of the samples contained less than 8.5 per cent. solids-not-fat; on the other hand, though the percentage of solids-not-fat is above 8·5 per cent. if water is added, the freezing point will be raised and the addition of water can be detected. The use of this test in legal cases has in several instances assisted materially in enabling a just decision to be made. It should be noted that the freezing point can only be

determined with certainty when the milk is fresh, and samples, when this test is desired, should reach the analyst as quickly as possible.

The Colour of Milk.

From the commercial point of view considerable attention is now given to the colour of milk, or, more accurately, to the colour and depth of the cream layer. It is common knowledge that cows produce milk which yields cream and butter of a deeper colour in summer when eating green foods, than in winter, and that Jerseys and Guernseys usually produce a yellower product than other breeds. Some years ago Palmer and Eckles (Ref. 29) showed that the cause of the yellow colour of butter fat is due to a substance called "carotin" (so-called, because it is the colouring pigment in carrots) which is commonly found in green plants, although it is usually masked by the green colouring matter chlorophyll. Green foods in general were found to be rich in carotin; hay of a green colour and new silage are less rich and carrots and other yellow roots are also useful sources of supply; on the other hand bleached hay, straw, old silage in which the carotin has been destroyed by fermentation, maize (both yellow and white) and all the common concentrates were found to be poor in carotin. The colour of yellow maize is due to a coloured substance other than carotin, which does not pass into the milk. When cows are given green foods the colour of the cream and butter becomes more yellow, and a store of colouring matter accumulates in the body; when only foods poor in carotin are given for long periods the body reserves become used up, and a white cream and butter fat is produced irrespective of breed. The Jersey and Guernsey breeds have a greater power than other breeds of transferring carotin from their foods to their milk and of storing it in their bodies, hence the yellow colour of the body-fat and skin.

The inference has also been made that animals with a yellow skin will yield milk of higher butter fat content, but Hooper (Ref. 30) made a careful examination of 165 Jersey cows, and came to the conclusion that there was no correlation in this breed between the milk and butter production and the amount of colour secretions. This subject and others of a similar nature have been studied by Thomson (Ref. 31), who states that in tests of the milk of numerous cows of the Guernsey and other breeds in which a colorimeter was used to measure the intensity of colour no relationship could be found between abundant skin secretion and the yield of milk or the per cent. of fat in the milk, nor even between skin secretions and the colour of the milk. It is stated that on numerous occasions cows with

the highest skin secretions gave milk of low intensity of colour. From this statement it would appear that the possession of abundant skin secretion is not necessarily associated with the power to transfer the pigment to the milk. Thomson also states that the chief American dairy breeds rank in milk colour from highest to lowest as follows :—Guernsey, Jersey, Ayrshire and Holstein, but that every breed shows a marked variation in intensity with different individuals, and that in every breed there are some cows which yield milk as deep in colour as many Guernseys.

V.—The Management of Milk and Milk Utensils.

In this section of this review the attention of breeders must first be directed to the revised edition of the publication entitled " Studies concerning the handling of milk," now issued by the Ministry of Agriculture and Fisheries as Bulletin No. 31 (Ref. 32). This bulletin contains an up-to-date summary of much research work carried out in this and other countries on the essentials of clean milk production, milking machines, clean milk competitions, " faults " in milk and milk products, and the properties of raw and heated milk, and a copy should be owned and studied by everyone interested in the improvement of the milk supply.

Keeping Quality in Relation to Fat Content.

The belief that rich milk does not keep as well as ordinary milk was commented on in this review last year, and a certain amount of evidence supplied by Barkworth was quoted in support of this opinion. This subject has also been studied by Thomas and Jones (Ref. 33), who report that the data tey have examined show a somewhat longer keeping quality for samples containing over 4·0 per cent. fat than for less rich samples. The comment made last year again appears justified, *viz.* that samples containing just over 4·0 per cent. fat cannot be described as rich milk, and that the keeping qualities of rich milk have not in fact been studied. In a recent publication (Ref. 34), Barkworth points out that apparently the keeping quality of afternoon milk is slightly less than that of morning milk, the difference being approximately 9 hours. This conclusion is based on the study of the average keeping quality of 2,808 samples of morning milk, and 3,032 samples of afternoon milk, taken in the course of clean milk competitions in three counties. Thomas has also studied this point (Ref. 35), and found that the afternoon milk has superior keeping qualities to the ordinary morning milk by approximately six hours. The latter workers also point out that morning samples are in

transit to the testing laboratories during the day while afternoon samples are in transit during the night and arrive at the laboratory at a slightly lower temperature. The samples reported on by Barkworth most probably had somewhat different conditions of transit, since the average temperature of the morning samples on arrival at the laboratory was lower than that of the evening samples (Ref. 36). It would appear necessary to have exactly similar conditions of production, handling and transport for morning and evening samples before the keeping quality of the milk produced at each milking can be determined, except in so far as the intention is to measure the keeping qualities of morning and evening milk plus the effect of the condition of the cows, utensils, etc., obtaining at each milking.

VI.—Cream Production and Buttermaking.

Buttermaking in Great Britain.

The total production of milk in England and Wales is estimated to be 1,117,000,000 gallons, and of this amount, about 80 per cent. is sold off the farms as whole milk, about 14 per cent. is made into butter, 5 per cent. into cheese, and 1·0 per cent., or thereabouts, into cream. To those accustomed to think of British dairy farming as consisting primarily of the sale of milk, the proportion used for butter-making appears high, but the amount of butter made in England and Wales and Scotland is estimated to be only some 11 per cent. of the national requirements. According to a Report on the Marketing of Butter and Cream (Ref. 37), recently issued by the Ministry of Agriculture, the estimated annual post-war production in Great Britain is 674,000 cwt., while the net imports are 5,370,000 cwt., hence it appears that the butter market is a vast potential outlet for home-produced milk and the Report suggests that the pressure of milk supplies may before long force the British dairy industry to exploit that market extensively.

The fact that 2½ to 2¾ gallons of milk from breeds other than those of the Channel Islands are required to make 1 lb. of butter, and that butter-making requires the expenditure of labour in separating, cream ripening, churning, etc., shows that over large areas of the country the sale of milk will always be preferred to butter-making, but the low price obtainable for surplus milk and the better price obtainable for home-produced butter of uniformly good quality has induced a considerable proportion of farmers, especially in those districts where stock-rearing and butter-making on the farm are still carried on, to give renewed attention to the conditions which assist in the production of good butter and to the causes of those faults which lessen keeping qualities and impair flavour.

Importance of Uniform Quality.

The Butter Producers' Association which has been formed in Devonshire has proved its value, and the inauguration of butter competitions in other counties has provided a means whereby the quality of farm butter may be improved and to a certain extent standardised. The sale of farm butter at a satisfactory price requires the production week by week throughout the year of a product of uniformly good flavour and aroma, texture, keeping quality, and colour. Thomas and Morgan (Ref. 38) have made a careful study of the factors influencing the keeping quality of butter made on Welsh farms taking part in county butter competitions. They measure keeping quality as the number of days which elapse between the date of churning and the time of discarding, and samples are discarded when a flavour or defect has developed which would condemn the sample for household use. The experience gained through the examination of over 400 samples has shown that the initial requirement is the production of clean milk, and that care in this direction is quite as important on butter-making farms as on milk-selling farms ; also the separator must be taken apart, cleaned and sterilised after each time of use, and the cream must be ripened under suitable temperature conditions and to the right degree of acidity. It is also suggested that an acidity of 0·45 per cent. is most suitable ; the use of a suitable "starter" in ripening the cream has resulted in an increase of two to three days in the keeping quality. The maximum removal of the buttermilk from the grains of butter is also essential and the water used for washing the butter must be free from undesirable bacteria.

Effect of Foods on the Consistency of Butter.

In addition to the conditions influencing the keeping quality of butter it is known that the colour and texture of butter is influenced by the foods consumed by the cow. The colour of milk and cream has been discussed above (*see* page 16), and our knowledge of the effects of different foods on the consistency of butter has been amplified by a series of experiments carried out at the Danish State Research Dairy, and reported by Hansen (Ref. 39). A number of groups of cows, so chosen that each group might be considered fairly representative of a small herd, received a basal ration of hay, straw, and turnips, and to this ration a different food was added for an experimental period for each group ; the milk obtained was taken to the Dairy, separated, the cream ripened in the usual way and the specific characteristics of the butter produced by each food was noted. It was found possible to classify the experimental foods

used into three groups, according to their effect on the butter, and this classification with a note as to the effect of each food is given below :—

Group	Food Material	Consistency of Butter
A	Dried Maize Mash	Very soft and loose.
	Sesame Cakes	Loose, soft and slushy.
	Soya Beans	Satisfactory, somewhat soft.
	Sunflower Cakes	Satisfactory, smeary.
	Linseed Cakes	Soft, smeary.
	Rape Seed Cakes	Soft, smeary.
B	Peanut (Earthnut) Cakes	Satisfactory.
	Cottonseed Cakes	Satisfactory.
	Dried Potato Mash	Satisfactory.
	Dried Grain Mash	Satisfactory.
	Sugar Beet Leaves	Satisfactory.
	Fish Meal	Satisfactory.
	Tapioca Meal	Satisfactory.
	Soya Bean Cakes	Smeary and good.
	Barley and Oats (Mixed)	Satisfactory.
	Turnips with Leaves	Rather satisfactory.
	Dried Blood	Satisfactory.
	Sunflower Seed Meal	Satisfactory.
	Wheat Bran	Satisfactory.
	Oats	Rather satisfactory.
C	Maize	Short, loose, rather soft.
	Barley	Rather satisfactory, somewhat dry.
	Rye Bran	Dry and crisp.
	Cocoanut Cakes	Dry and crisp.
	Babassu Cakes	Dry and crisp.
	Soya Bean Meal	Dry, crisp and short
	Palm Kernel Cakes	Dry and crisp.
	Rye	Short, dry and hard.
	Wheat	Hard, dry and crisp
	Vetches	Very dry and crisp.

The above groups may be briefly described as : A=the foods which when added to a basal ration of hay, straw and turnips have given a soft and smeary butter ; B=the foods which have given butter of normal consistency ; C=the foods that have given a hard butter of crisp consistency. In ordinary feeding practice a mixture of foods may be more easily obtained and more economical, and it is stated that butter of satisfactory consistency has been obtained from a mixture made up of 40 per cent. of foods in group C, 40 per cent. from group B, and 20 per cent. from group A. In another report (Ref. 40) on the same series of experiments it is stated that summer feeding stuffs such as pasture and green forage crops yield a soft butter, and this defect in consistency may be more or less overcome by the addition of small quantities of the concentrates in group C. The winter period foods, such as hay and straw, give a hard and solid butter, hence the judicious use of foods in group A

may then be beneficial, further, when definite changes in the foods from different groups have been made the effect on the consistency of the butter has been rapid, and a complete change has occurred within seven to eight days.

It should be noted that the effect of foods on the consistency of butter implies a change in the chemical constitution of the butter fats, and does not necessarily indicate an increase in the percentage of fat in the milk.

Cream Production.

The Report on the Marketing of Butter and Cream already referred to (Ref. 37), contains an instructive section on the supply and demand, and on the quality and preparation of cream for sale. It is pointed out that the quantity of cream imported into the United Kingdom (and almost entirely into Great Britain) has increased remarkably during recent years. This is shown by the following figures :—

Year	Cwt.	Gallons[1]
1901	6,198	77,000
1913	9,078	113,000
1922	11,046	137,000
1925	88,129	1,093,000
1929	137,794	1,709,000
1930	134,600	1,669,000

It will hardly be contended that the increase in imports shown above is due entirely to lessened production at home, hence there must have been a considerable increase in the consumption of cream. There is, in fact, reason to believe that the trend of cream production since the war has been upwards, but it is obvious that a greatly increased cream market is available to the British farmer. The demand, however, as the Report points out, is markedly seasonal during the year, it is at its highest from June to August—the soft fruit season—then falls, to increase again at Christmas time. The demand also varies greatly from day to day ; some 61 per cent. of the week's demand occurs on Sunday and Saturday, with an average of about 8 per cent. for the other five days. These variations in the demand increase greatly the difficulties which the supplier has to overcome and increase the price, but it is pointed out that the big increase in the consumption of canned and bottled fruits in recent years has tended somewhat to even out the consumption of cream throughout the year.

The kinds of cream usually vary according to the percentage of fat, and, as a rule, the home produced supplies consist of (*a*) a thick or heavy cream containing about 50 per cent. fat,

[1]The conversion figure used to arrive at the volume of cream is 9.85 lb. per gallon.

sold either raw or pasteurised, (*b*) clotted cream, containing 50 to 60 per cent. fat, and produced almost entirely in Devon, Somerset and Cornwall. It is stated that a thinner or "light" homogenised, pasteurised cream of about 20 per cent. fat has been put on the market in some districts with good results, and it is suggested a larger and more regular demand could be developed if a product of this type, but of a definite standard for fat content, were put on the market generally and offered at a lower price than that of ordinary thick cream. The importance of sweetness or good-keeping quality and flavour is emphasised and a National Mark Scheme for British cream is outlined. Farmers interested in butter and cream production will find the Report well worth perusal, and those situated near a promising market may find cream production and sale more profitable than butter-making.

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DISEASES OF ANIMALS: PREVENTION AND TREATMENT

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I. FOOT-AND-MOUTH DISEASE.

Survival of the Virus.

The practical importance of determining the length of time the virus of this disease may survive under various conditions is obvious, and in this country much information on the subject has been gathered by the workers for the British Foot-and-Mouth Disease Research Committee (Refs. 1, 2, 3 and 4). The recently published Fourth Report of this Committee (Ref. 4) gives further details on this point, particularly concerning the survival of the virus in animals and animal products after death.

Survival of Virus in Dried Blood.—One of the principal factors in determining the duration of survival of the virus is the temperature at which it is stored, low temperatures favouring long survival. The particular kind of surface on which the virus is placed is also of consequence, and the importance of this factor in the case of dried blood containing virus has been noted by W. H. Andrews and his co-workers at the Committee's Field Research Station at Pirbright. While the virus in dry blood survived 2 or 3 days only at ordinary temperatures (59° to 68°F.) on glass, iron, zinc, tile, brick or wood, it was remarkable that on boot leather or on rubber from a gum boot its life was prolonged to from 80 to 102 days respectively. Blood, smeared in the fresh condition on the hides of guinea pigs and then dried, retained its infective properties for 89 days.

Survival of the Virus in the Carcases of Infected Animals.—In the Second Progress Report of the Committee (Ref. 2) F. C. Minett related experiments which showed that under conditions met with in the meat trade the virus could survive for long periods. For example, it was found in preliminary experiments with guinea pigs that the virus in lesions of the feet remained active in different pickling solutions of salt,

nitre, sugar, etc., at a mean temperature of 62°F. for periods up to 35 and 49 days. Virus in crushed bones was infective for pigs by feeding after 42 days' storage at trade chilling temperature (28°–30°F.), whether the bones were derived from a bacon carcase or the carcase of an ox. Bone marrow from a beef carcase and a bacon carcase stored at trade freezing temperature (10°–15°F.) still contained virus after 76 days.

These experiments were intended to throw light upon the possibilities of foot-and-mouth disease being introduced into Great Britain through the medium of imported meat. They established the principle that the virus might survive in butchers' carcases long enough to be a source of danger, but no large-scale experiments were carried out to show how long carcases might remain infective. This work has been continued by W. H. Andrews and his colleagues at Pirbright.

From experiments on guinea-pigs further observations are recorded on the survival of the virus in the different organs, removed after death and stored separately at chilling temperature (28°F.). It was found that virus was still active in the tongue, lungs, heart, liver, kidney, bone marrow and tendons at periods ranging from 62 to 145 days after the death of the animal. On hessian or stockinette, materials used in the meat trade for wrapping chilled and frozen carcases, small particles of skin containing virus were found infective after about 45 days at room temperature (56°–87°F.) or at cold storage temperature (28°–35°F.).

In the case of cattle, the experiments were arranged so as to simulate as closely as possible the conditions of the imported meat trade and were carried out in a special plant built at the Research Station. Adult cattle were allowed to acquire the infection by contact with other cattle which were reacting to inoculation with virus. When they had reached the stage of the disease which was believed to be the most infective they were slaughtered and bled by a trained butcher. After the carcase had been dressed, the quarters were stored at trade chilling temperature (29°F.) and the offals (tail, kidneys, liver, tongue, cheeks, heart, skirt and gall-bladder) wrapped in stockinette and hessian, were placed at trade freezing temperature (15°–18°F.). Pieces of stockinette and hessian saturated with blood at the time of slaughter were also stored at 18°F. The hides were placed on the floor of a loose box at the ordinary atmospheric temperature and salted. It was intended that the carcases should be highly infective at the time of slaughter. The degree of infectivity, however, varies very much in different animals and it is not always easy to decide upon an appropriate moment for slaughter. When the first three cattle were killed, they were found to have so little virus

in the blood that the experiment was abandoned. In a second experiment three cattle were infected by means of another strain of virus, the blood was subsequently proved to be infective at the time of slaughter, and from each of the three carcases virus was recovered later. From the first the bone marrow proved to be infective when inoculated into pigs on the 13th and 33rd days after slaughter. From the second carcase, 14 days after slaughter, the tongue and cheeks were infective for pigs, and on the 33rd day the cheeks infected two pigs by inoculation and two by feeding. Wrapping materials soaked in the blood of the second and third animals at the time of slaughter and stored at 18°F. were also infective to pigs by inoculation 40 days after slaughter. The remainder of the offal of these three animals did not prove to be infective 13 days after slaughter nor did the salted hides stored at out-of-door temperatures. In one instance, however, a salted hide was found to be still infective, by feeding, for one out of two pigs after 46 days' storage.

In the third experiment six fat cattle were exposed for 12 hours to two cows suffering from foot-and-mouth disease and four of them reacted. Small quantities of the offals and bone-marrow of these four animals after 33, 24, 7 and 22 days respectively at freezing temperature failed to infect pigs by inoculation. Nevertheless, inoculation of a larger quantity of bone-marrow taken from one of the carcases 40 days after slaughter caused infection in pigs. Similarly, when large amounts of bone-marrow with crushed bones taken from a second carcase after 80 days at chilling temperature were fed to six pigs, which at the same time were inoculated with small amounts of bone-marrow, all of them became infected with foot-and-mouth disease. This result is notable on account of the lengthy period during which the virus was shown to survive in bone-marrow at *chilling* temperature.

These observations make it clear that under the conditions of the import meat trade the virus can remain alive for at least some weeks. The actual period of survival will vary no doubt from carcase to carcase, and may eventually be found to be longer than any yet recorded. The duration of survival will depend in the main upon the degree of infectivity at the time of slaughter, and perhaps also upon the particular strain of virus present.

Effect upon the Virus of Repeated Freezing and Thawing.—Experiments bearing on the investigations just referred to are reported by I. A. Galloway (Ref. 4) from the National Institute for Medical Research, London. It has been recognised for a long time that many ordinary bacteria survive freezing at very low temperatures, but that repeated freezing and thawing may

have a deleterious effect. There is also a good deal of evidence that many filterable viruses survive for long periods at very low temperatures, but the effect of repeated freezing and thawing has not received much attention. In the experiments of Galloway on this point, no diminution in the activity of the virus was found. In some experiments the virus suspended in tap water, saline solution or blood was frozen and thawed 25 or even 70 times without causing any loss of activity. This was so whether the virus was present in high or low concentration. The work was then extended to the carcases of guinea-pigs which had been killed at the height of their infectivity, bled and dressed. Such carcases frozen for 26 days and then kept at 64°F. for 5 days contained active virus in the bone-marrow. The same was true for the bone-marrow of carcases which had been frozen and thawed six times in the course of 30 days or 21 times during a period of 6 days. In the latter case appropriate methods of testing failed to show that the virus had suffered any appreciable loss of potency. It may be concluded, therefore, that temperature variations to which carcases are subjected in the meat trade are unlikely to have any destructive effect upon the virus.

Survival of the Virus in Milk and Dried Milk.— It is well known that the milk of animals may contain the virus during the acute stages of the disease, and there are further opportunities for infection when vesicles form on the teats. On the Continent the use of infected milk is believed to be a means of spreading the disease, since in the unheated state it may infect calves or pigs which are fed on it. Detailed experiments have been carried out by I. A. Galloway (Ref. 4) to see how long milk remains infective in the liquid state and after it has been dried. The resistance of the virus to heat under these conditions has also been investigated.

It was found that the virus, added to fresh milk which has been "chilled" immediately after being drawn from the cow and subsequently kept at a low temperature (about 40°F.), can survive for about 15 days. If such milk, subsequent to being chilled, is kept at a higher temperature (about 60°F.) the virus will survive in it for about 6 days. After these times souring is liable to take place and this renders the virus inactive. If souring is prevented by using for the experiment milk which has been previously sterilised by heat, and then kept free from bacterial contamination, the virus survives in it for much longer periods, *e.g.* up to 35 days at 60°F. and 50 days at 40°F.

It is conceivable that under natural conditions feeding stuffs or bedding material might become contaminated with milk containing virus. The influence upon survival of the virus of the nature of the surface contaminated has been referred

to previously in this article. It was decided, therefore, as a matter of practical importance to find out how long such materials would remain sources of infection. The results showed that when milk containing virus was lightly sprayed on hay, bran or straw stored in a dark place at ordinary temperature, these materials remained infective for about 17 days. On bran, however, a material previously found by Burbury (Ref. 3) to favour survival, some degree of infectivity could still be demonstrated after 32 days. Another striking example in the reverse direction is that of wood. It was ascertained by Minett (Ref. 3) that on hard wood the virus, contained in shreds of guinea-pig skin, survived for a much shorter time than on some other surfaces, *e.g.* glass. This has been confirmed by Galloway, who found that virus in milk sprayed on pieces of hard wood failed to survive for 2 days.

The experiments carried out by Galloway on the survival of the virus in milk, which is first dried and then subjected to various degrees of heat, are of importance in relation to the possibilities that the disease might be imported into this country through the medium of commercially dried "milk powders." Such milk powders may be used for feeding calves, either alone or incorporated in calf-foods, or residues may be used for feeding pigs, or discarded tins which had contained such milk powder may be thrown in places to which cattle and pigs have access. It is feasible to assume that if regulations were lax, infected milk might reach factories where this product is made. In Europe, two principal methods are in use for the manufacture of milk powder, known respectively as the "roller" and the "spray" process. In the former method milk is allowed to run on to the surface of rollers, which are heated internally by steam and on which the milk rapidly dries to form a layer which is automatically scraped off as the rollers revolve. The time the milk is in contact with the rollers is estimated to be about 5 seconds, or even less. It has been stated that the temperature of the surface of the rollers is a good deal below boiling point and with certain kinds of plant it may be very much less. In the "spray" process the milk is blown through a fine sprayer into a hot chamber, in which the milk dries in the form of flakes. The flakes are removed by an air current or by some other method. The temperature in the hot chamber has been estimated in some types of plant to be about 176°F., but frequently it may be lower. In any case the milk will be at a lower temperature than that within the chamber itself, as it is evaporating. Manufacturers are agreed that in order to produce powder of good quality, milk should be dried at as low a temperature as possible. For the same reason pasteurisation of milk before drying is usually omitted.

It has not yet been possible to test the survival of the virus in milk dried under actual trade conditions, but the following results, obtained under laboratory conditions simulating in principle those of the trade, afford useful indications. It was found, in the first place, that milk contaminated with virus and then dried rapidly may remain infective for at least a month in a rubber-corked tube. There was no reason to suppose that under these conditions the dried milk would not have remained virulent for a much longer period.

In testing the effect of heat, contaminated milk was spread in thin layers on the bottoms of shallow glass dishes. In the wet state the virus in such milk was destroyed within 5 seconds at a temperature of 149°F. If, however, the milk was partially dried prior to the application of heat, *i.e.* to the point where it could be scraped off the dish as fine scales, the virus was so resistant that heating to boiling point (212°F.) for 10 seconds or to 167°F. for 5 minutes failed to destroy it.

Sources of Infection.

In considering this subject it is necessary to distinguish between agencies which may be responsible for the initiation of fresh outbreaks and those which may operate in outbreaks already established. Much information relating to this subject is contained in the Fourth Progress Report of the Foot-and-Mouth Disease Research Committee (Ref. 4).

The Origin of Initial Outbreaks.—Experience concerning the reappearance of the disease in this country following the slaughter-out policy has recently been summarised by Sir Ralph Jackson (Ref. 5). Out of 5,554 centres of infection which have appeared in the course of the last 20 years, where restocking has taken place from 4 to 18 weeks after the disinfection, the disease has recurred in only 57 centres and in 13 of these there is reason to think that it was reintroduced with the replacement animals.

In the case of initial outbreaks, the veterinary officers of the Ministry of Agriculture make an attempt to discover the source. In the past, the evidence has usually pointed to the introduction of the virus from abroad in such products as meat, bones, hay, straw or vegetables. In consequence, research workers have been at pains to discover to what extent and under what conditions the virus is capable of surviving on such materials.

Sources of Infection during the Course of Outbreaks.

1. *The Susceptible Farm Animal.* Once an outbreak has started the living farm animal constitutes the main source of infection.

In order to throw further light on the degree of infectivity of animals at various stages of the disease, experiments were undertaken at the Research Station of the Ministry of Agriculture at Pirbright. When virus is injected into susceptible cattle, there is a period of incubation lasting several days during which the animals remain in apparently normal health. This phase is followed by a rise of temperature, which may last for two or three days, and it is at any time during or immediately after this febrile stage that the vesicles or blebs characteristic of the disease may be expected to appear. It was ascertained that virus is generally demonstrable in the blood during but not usually before the rise of temperature, and that it exists in greatest concentration within a few hours, or less, of the appearance of vesicles. At about this time the virus may also be excreted in the milk and in the urine, though experiments at Pirbright have shown that in the latter it is present irregularly and generally only for short periods.

An important point to be determined was the earliest stage at which cattle suffering from foot-and-mouth disease become infective for other animals. It is true that information bearing on this point can be adduced from what has just been written, but it was thought desirable to study the question further by means of experiments under natural conditions. For this purpose, susceptible cattle and pigs were exposed to infected cattle at various stages of the disease. The results, with one exception, gave no support to the view that animals are infective during the incubative stage or during the febrile stage before the formation of vesicles. On the other hand, the experiments left no doubt that the maximum infectivity occurs immediately after the rupture of vesicles.

The Decline of Natural Infectivity.—On the basis of experiments carried out for the most part in Germany, it is generally believed that the virus can only rarely be recovered from cattle as late as the eleventh day of the disease, even when scrapings from the mouth and tongue are used as test material. Lebailly (Ref. 8), in France, in 1922, brought forward evidence to show that as early as 4 or 5 days after the appearance of vesicles cattle and the stalls in which they have been confined usually ceased to be infective for fresh animals. On the other hand, it has been supposed by some that the virus may at times survive in fissures or cracks about the hoofs of recovered animals and that this is the explanation of the recurrences of the disease which are occasionally observed on the same premises. It has also been believed that the virus may survive for some days in the dried state on the coats of cattle, if the animals are not thoroughly disinfected after recovery.

Observations bearing on these important practical points have been made at Pirbright. Cattle which had passed through an attack of the disease were used as the sources of infection, a period varying from 1 to 14 days after the rupture of their vesicles being allowed to elapse before susceptible test animals (cattle and swine) were placed in contact with them. The period of exposure of the test animals varied from 6 days to several weeks. It should be noted that in most instances the experiments were conducted in the boxes, which had been occupied by the infected animals during at least a part of their reaction, and that as a rule the boxes had been only partially cleaned and in no case disinfected, prior to the infectivity experiment. The results showed that up to the fourth day after the rupture of the vesicles the contact animals became infected, though not invariably so. In no instance, however, did the contact animals become infected when exposed to cattle, the vesicles of which had ruptured more than 4 days previously. While these results, therefore, coincide with the findings of Lebailly and other observers, they are admittedly a little difficult to explain in view of the proved long survival of the virus in the outer world, and further experiments on the subject seem desirable.

2. *Small animals as a source of infection.* When an outbreak is in progress, the infected farm animal no doubt is the greatest source of danger in spreading the disease. There is, however, another possibility to which a certain amount of attention has been paid, *viz.* that infection may be spread through the agency of animals living on farms in a wild state. In this connection mammals such as rats, mice, rabbits, hedgehogs, foxes, dogs and cats, or birds such as rooks, sparrows and starlings, have been looked upon as possible transmitting agents, either because they might themselves become actively infected or because they might transport the virus in a passive manner from one place to another. Further information concerning the infection of small animals is given in the Fourth Progress Report of the Committee.

Rats.—The possible importance of wild rats in the natural spread of the disease was emphasised in 1924 by Beattie and Peden (Ref. 6) at Liverpool, and again in 1928 by Beattie, Morcos and Peden (Ref. 7). These workers succeeded in infecting wild rats by feeding them with virus from guinea-pigs, the virulent material being mixed with crushed bones in order to increase the liability to inoculation by producing injuries to the mucous membrane with spicules of bone. It was found by others, however, that, though wild rats can be infected by large doses of virus, and though the disease can be conveyed from rat to rat by inoculation, the disease does not spread among

rats by contact and in a number of instances it tended to die out fairly rapidly in this species. In 1929 it was decided by the Committee working at Pirbright to re-examine the question following the discovery of two cases, from different areas, of naturally contracted foot-and-mouth disease in wild rats.

A veterinary inspector of the Ministry of Agriculture, whilst on duty at an infected farm in Yorkshire, found the place to be infested with rats, many of which appeared to be lame and had abrasions or ulcers on the feet. Four of these animals were forwarded to Pirbright and with material from one of them foot-and-mouth disease was set up in guinea-pigs. In this instance, however, it was not possible to transfer the infection to other guinea-pigs. At about the same time a rat was caught at the experimental station, but, although showing feet lesions, the animal could not be regarded as definitely suspicious of foot-and-mouth disease. Nevertheless, material from its feet set up the disease in guinea-pigs. By means of this rat virus, infection could be passed through guinea-pigs and rats in series and could also be transmitted to swine. Swine were infected by feeding them with the bodies of guinea-pigs inoculated with the rat virus. Wild rats could be infected by inoculating virus simultaneously into the hind feet and into the muscles, and in about half the cases tried infection was successfully conveyed by feeding with carcases of infected rats. Experimentally, the disease was found to spread from inoculated rats to others which were kept in contact with them, and from these contacts again to others through association in the same cages. The signs of infection in rats consisted of vesicles on the feet and toes, on the tongue and lips and on the tail. The diseased areas on the tail were mostly inconspicuous and were indicated by small ulcers or crusts on any part of the tail. Altogether 132 rats caught at the Pirbright Experimental Station have been examined, and six in all have been found to be infected. Further experiments showed that rats could be infected, not only with virus derived from a natural case in the rat, but also with virus originally obtained from cattle through the medium of guinea-pigs. Fully-grown wild rats could be infected much more easily than young ones, while tame rats were definitely less susceptible than wild ones.

Rabbits.—It has been repeatedly shown that tame rabbits can be infected with the virus by inoculation, and it has been found (Ref. 2) that the disease occasionally spreads from infected to healthy rabbits, probably as the results of fighting, when they are confined at close quarters. An experiment carried out by Mrs. Y. M. Gibbs (Ref. 4) indicated that wild rabbits also can be infected by inoculation, but, since the disease did not spread to others in the same cage, it can be

taken as probable that wild rabbits are not very susceptible to infection by contact.

Hedgehogs.—It was recorded in 1927 by F. C. Minett (Ref. 2) that hedgehogs could be infected with the virus of foot-and-mouth disease. Two adult hedgehogs were inoculated into the muscles with virus from guinea-pigs and both animals showed vesicles on the feet and died within 15 days. A large number of experiments with these animals has since been made at the Lister Institute by Y. M. Gibbs and J. T. Edwards (Ref. 4). Hedgehogs after inoculation show vesicles on the feet, tongue and snout, and usually become very ill and die within a week or ten days. Infection may also be sometimes transmitted by feeding. When healthy hedgehogs are kept in contact with those which have just been inoculated, they also showed signs of infection 3 to 5 days after the onset of the disease in the former. The disease was also severe when the infection was thus acquired naturally by contact. When the virus is passed from hedgehog to hedgehog its power of infecting these animals greatly increases, leading to a severe and uniformly fatal disease, spreading rapidly by contact. Diseased hedgehogs may spread infection to guinea-pigs kept in contact with them, probably chiefly through wounds on the feet, but hedgehogs did not appear to become infected by contact with infected guinea-pigs. It is noteworthy that the hedgehog is the only species of animal besides farm animals in which rapid spread by contagion of a severe form of the disease is known to occur, though experiments with rats in captivity showed that in these animals also transmission by contact occurs fairly often. Moreover, the hedgehog is the only animal in which the established disease shows a high mortality. It is a curious fact, however, that the infection soon dies out in an infected enclosure, in the absence of living animals, even though all soiled litter is allowed to remain. No evidence was obtained that hedgehogs can recover from the effects of the disease and, although remaining outwardly healthy, can become carriers and sources of infection.

It may be said in conclusion that the discoveries in connection with the susceptibility of small wild animals are of extreme interest. Nevertheless, when the incidence of the disease in the field is considered, it is not clear at the present time that rats or other small animals play any important part in dissemination.

II.—IMMUNISATION OF PIGS AGAINST SWINE FEVER.

In attempting to reduce the losses caused by swine fever, three possible lines of attack are available.

Firstly, a slaughter-out policy similar to that which has been adopted in Great Britain against foot-and-mouth disease; secondly, sanitary measures which include the proper disposal of dead animals, quarantine of infected premises, and disinfection; thirdly, some system of immunisation, *i.e.* of increasing the resistance of susceptible animals.

The first policy, which would have for its object the total eradication of swine fever, would succeed with difficulty, but in any case it is now recognised as impracticable in countries where the pig population is dense and where the disease is deeply rooted. Sanitary measures are capable of reducing to some extent the prevalence of swine fever, but under ordinary conditions cannot be expected to control the disease effectually when it is spreading rapidly. The aim of protective inoculation is not so much the total eradication of the disease as the elimination of actual losses and such a measure might be justified in a country where repeated outbreaks sometimes render pig-rearing difficult or impossible.

At the International Veterinary Congress held in London in 1930, reports (Ref. 9) on the control of swine fever were submitted by Dr. M. Dorset (United States) and by Drs. W. Geiger and W. Nusshag (Germany), and the subject was also discussed in Paris in 1931 at the International Office for Epizootic Diseases, following a report by Professor F. Hutyra (Budapest) (Ref. 10). The purpose of this article is to refer briefly to procedures for dealing with swine fever, which have been adopted in the United States and in certain of the larger European countries, to describe some of the results achieved, and to set out current opinion on the subject.

It has been known for a number of years that it is possible to protect healthy pigs against swine fever by means of inoculation. If pigs which happen to have recovered from an attack of the disease are reinjected several times at intervals with blood from pigs suffering from the disease in the acute stages, their blood-serum, when injected into healthy pigs, is capable of rendering them insusceptible to the disease. The reinoculations of virus in such recovered pigs have the effect of strengthening the immunity of, or, as it is called, "hyperimmunising" the animals. Unfortunately, the protective effect afforded even by so-called "hyperimmune" serum (*i.e.* blood-serum from hyperimmunised pigs) is lost for all practical purposes after a fortnight, and this severely limits the use of serum on the farm. It has been found, however, that if at the time of giving the serum, a dose of blood containing the virus of the disease is injected at another part of the body, the immunity, instead of being a temporary one, becomes "active" or lasting, to such a degree that the animal is rendered re-

sistant to the disease for the rest of its natural life. The procedure of injecting virus as well as serum in this way is spoken of as the "simultaneous method" of immunisation. A similar state of active immunity also follows a natural attack of swine fever or an injection of virulent blood, should the animal be fortunate enough to survive, but whereas the immunity thus acquired is at the expense of serious interference with health, the simultaneous method, when properly conducted, produces a strong immunity although symptoms are negligible or entirely absent. A similar result is likely to follow if, immediately after treatment with serum, healthy pigs are allowed to mix with infected pigs. This is really a process of natural vaccination, but since in practice it cannot be assumed that the animals will absorb a sufficient amount of virus, a lasting immunity cannot be assured to all the animals.

In the United States the use in outbreaks of protective serum alone has not proved to be satisfactory, but since 1913 the simultaneous method has been practised on a vast and gradually increasing scale in infected herds and in herds which are in danger of becoming infected. It is recommended that serum alone should be administered to all pigs that are visibly sick or which show a temperature exceeding 104°F., and that all the remainder should be given the simultaneous inoculation. It is necessary to take the temperature of pigs outwardly healthy, because a rise of temperature is frequently the only sign of infection present, and in any case usually precedes by several days the appearance of symptoms. Some 20,000,000 pigs, that is, about 34 per cent. of the total hog population, are now being inoculated annually, and this has brought about a gradual decline in the prevalence of the disease, losses having declined to the record minimum of 30 per thousand in 1929. As pointed out by Dorset, this result has been achieved in spite of a constantly increasing movement of animals and in spite of the fact that since 1917 millions of pigs have been returned from public markets to farms for feeding purposes, a practice not previously permitted.

In Germany, until five or six years ago, the use of serum alone in infected herds was chiefly favoured. The procedure was to remove for immediate slaughter all animals showing symptoms of the disease, to record the temperatures of the remainder and to inject them with serum. Most of the animals showing a high temperature at the time of serum inoculation were likewise slaughtered within a few days. The other treated animals were expected to come into natural contact with the disease, but, as it was considered important that strong infections should be avoided, frequent disinfection of the animals' surroundings was recommended as an additional

measure. The results obtained by this method were not unfavourable, when at the commencement of operations a suitable amount of infection was present in the herd. In practice, however, the system is liable to break down, on account of the impossibility of selecting the most favourable moment for beginning serum treatment. Thus, it is often found either that the disease has progressed much too far, or that there is too little infection in the herd. In the latter case the healthy pigs may not get an opportunity of coming in contact with infection before their serum protection has worn off. Shortly afterwards, when their susceptibility returns, they are liable to become the centre of a fresh outbreak, necessitating a second intervention with serum. On account of these difficulties, the simultaneous method has been used in Germany, since 1927, for infected herds, where the owner is agreeable and where the disease has not progressed too far. The method has proved to be very successful and, in the opinion of Geiger (Ref. 9) who is Director of the Swine Fever Station at Eystrup in Germany, 95 per cent. of healthy inoculated pigs can be saved on an average. All animals showing symptoms are removed for slaughter and the temperatures of the remainder are recorded. Feverish animals are regarded as infected, and, unless ready for immediate slaughter, they are given a double dose of serum but no virus. There is no necessity that they should be isolated. Animals which have a normal temperature and which are otherwise healthy receive a generous dose of serum and at the same time a dose of fully active virulent blood. In order to provide the virus, a selected animal on the infected premises is sometimes used. In this case it is important that the animal chosen should be killed when suffering from swine fever in the acute stage and, as proved by post-mortem examination, in an uncomplicated form. The virus must be fully active to ensure that the reaction takes place quickly after inoculation at a time when the serum protection is at a high level.

In Hungary, for a number of years protective serum alone was used for the outwardly healthy animals in infected herds, and, as in Germany, the procedure often achieved considerable success when used in the early stages of an outbreak. Statistics published by Hutyra (Ref. 10), relating to 836 herds (110,198 animals), showed that in about half the herds the outbreak was immediately stopped and that in one quarter the losses did not exceed 10 per cent. of the animals. However, in the remaining quarter of the herds the results were less favourable or even bad. This was considered to be due in part to the co-existence of other diseases, but chiefly to the fact that the serum was given too late in the outbreak or because the treated

animals had no opportunity of mixing with infected pigs and so acquiring a lasting immunity. Experience has shown that, if favourable results are to be obtained by means of serum alone, not more than 10 per cent. of the animals in the herd should be showing symptoms at the commencement of operations and not more than 5 per cent. should have been affected previously. The best results are, in fact, dependent upon the possibility of injecting the serum at a moment exactly favourable, and, as previously explained, it is this difficulty which frequently leads to the failure of the serum alone method in practice. In consequence, the simultaneous method of inoculation has come into extensive use in Hungary and some 200,000 pigs are now vaccinated annually. Results for the years 1926–29, relating to 580 herds (121,597 animals), showed that in the great majority of herds the results were favourable, no losses due to the vaccination having occurred in 40.5 per cent. herds (33,702 animals) and in 33 per cent. herds (49,210 animals) the losses did not exceed 5 per cent. In 26 per cent. of the herds (38,685 animals), however, the losses ranged from 5 to 35 per cent. (average 19 per cent.). It ought to be mentioned, however, that in some of these cases the herds were already badly infected at the time of vaccination. For 734 herds (155,119 animals) no information was available, and as it is certain that failures are communicated more frequently than successes, the figures given would appear in a still more favourable light, if the full results had been available. In any case, the results are striking when it is remembered that under natural conditions the losses from swine fever may reach 50 to 80 per cent. or even more.

In Austria also, according to Gerlach (Ref. 9) the simultaneous method is preferred to the use of serum alone. Animals showing symptoms and any that are fit for slaughter are removed, and all the remaining pigs are injected with serum and virus. It has been found advantageous to subject both sound and feverish animals to these inoculations, and to include pregnant sows, sows in milk, and suckers which are at least 3 to 4 weeks old.

In France it is considered that the incidence of swine fever is not high enough to justify the extensive use of the simultaneous method; outbreaks are usually isolated and sanitary measures suffice to bring them under control within a few weeks.

In Great Britain attempts were made to deal with the disease by means of slaughter-out methods, but these were not successful. Following the final report in 1915 of the Departmental Committee on Swine Fever, general serum treatment was introduced, with the owner's consent, on suitably infected premises. Arrangements were made for the injection

of serum into pigs outwardly healthy, as early as possible after the disease was diagnosed by the local veterinary inspector. The owner was then advised to allow the treated animals to mix with the visibly affected pigs, in order that they might acquire a lasting immunity. The results of the first year's working showed that under these conditions serum treatment, when applied early in the outbreak, is of considerable value in saving pig life on infected premises. Unfortunately, there was much evidence that in many instances the disease was not reported promptly; in fact, in the experience of Stockman (Ref. 11), on an average some 30 per cent. of the pigs were dead or visibly ill before there was an opportunity of applying treatment. It was largely owing to this difficulty that the provision of free supplies of serum as a national measure for combating swine fever was discontinued at the end of 1922. In this country the disease is now controlled by sanitary measures, and pig keepers are particularly recommended to report suspected cases without delay. Serum treatment may be carried out by the owner at his own expense, and the veterinary inspectors of the Ministry of Agriculture give advice as to whether the conditions are suitable for this treatment.

From what has been said above, benefits are clearly to be derived from artificially raising the resistance of pigs to swine fever. The main disadvantages of swine fever serum, apart from its comparatively high cost, are that it affords a temporary protection only and that it does not cure, except possibly very shortly after infection. Even this temporary protection may be of great value, however, in special cases, for instance, when animals have to be exposed to the risk of infection at markets or shows. As stated above, in infected herds the results following the use of serum alone largely depend upon the extent of the disease at the time when serum is injected and upon the opportunities for the treated animals to acquire a lasting protection under cover of the serum. It is unfortunate that the conditions in practice are so often opposed to the successful use of serum. Nevertheless, many favourable results have been recorded, and according to Geiger (Ref. 9), the use of large doses of potent serum in outbreaks enable from 50 to 75 per cent. of feverish pigs to be saved.

There is general agreement that the simultaneous method is to be recommended in countries where the pig population is dense, where the disease is permanently established, and where losses are heavy. In the United States, for example, the method has proved effective in cutting out the tremendous losses which occurred, especially in large herds, prior to vaccination, and attention is again directed to the results which have been obtained in Hungary. On the other hand, since the

method involves the use of living virus, there are strong objections to the simultaneous method in countries where outbreaks are usually few and scattered, and especially where the disease can be controlled by sanitary measures or by means of serum alone. In short, the serum-virus method is only justified in countries where the disappearance of the disease cannot be hoped for and where without it pig-rearing would be impossible.

It remains to refer to the circumstances in which the simultaneous method may be adopted and the conditions which make for success. In the first place, it is not intended for herds which are free from the disease and are situated in a clean district. It is generally admitted that there can be no strong objection to the method in herds which are already infected, but there is some diversity of opinion as to the procedure to adopt in healthy herds which are situated in infected districts and in imminent risk of infection. A decision as to the best practice in any particular case can only be reached after full consideration of the circumstances. In the United States, as a general rule the simultaneous method, involving the use of full doses of serum, would be recommended in such herds, unless it were possible to arrange for their immediate inoculation in the event of swine fever developing. In Germany, serum alone has been used in such herds with results which are said to be very successful. In general, pigs already showing symptoms of swine fever are not inoculated with virus, and with pigs having a temperature exceeding 104°F., serum alone is sometimes recommended. Apart from these, all pigs on the premises, which are in normal health and not less than about 6 to 8 weeks old, may be given serum and virus. Under normal conditions this leads at most to a slight rise of temperature and loss of appetite, lasting for three or four days during the second week. In quite one-third of the cases there are no outward signs of ill health. It has been stated that sows in advanced pregnancy are liable to abort, and for this reason serum treatment alone is sometimes recommended for these animals. In the experience of Gerlach, however, in Austria, not more than 2 to 8 per cent. of sows abort and there is less objection to the simultaneous method for pregnant sows than to the use of serum alone. Some losses are to be expected, however, among the first pigs born after the vaccinations. The procedure which should be followed in the case of suckers has often been discussed, and it is generally agreed that pigs should not be subjected to the simultaneous inoculations during the first few weeks of life. In place of this, it is usually advised that they should be given serum, and that treatment with serum and virus should be deferred until shortly after

weaning. It is of the greatest importance that only healthy animals should be vaccinated, and that during the following three or four weeks they should be well fed and kept in warm dry surroundings. During this time no operations, *e.g.* castration or other inoculations, should be made. Pigs which are unthrifty or suffering from other diseased conditions, such as chronic pneumonia, swine erysipelas, rickets or infestation with worm parasites, should not receive virus, and the same applies to pigs which have recently been castrated. Such animals should be given serum only, or disposed of, as the case requires.

As to the reagents used, it is essential that they should be prepared in institutions where their potency will be standardised, and that they should be subject to State inspection. Generous doses of serum should be used, since in this way so-called "vaccination disease" may be obviated to a large extent, without interfering with lasting immunity; further, the inoculation must be made by skilled operators who will ensure that only healthy animals are treated and that the reagents are used in the proper dosage. Finally, the earlier in the outbreak the inoculations are carried out the better, as it will then be possible to protect a larger number of pigs. In fact, as with the serum-alone treatment, the final success is in direct relation to the promptitude with which the outbreak is reported and dealt with.

One of the principal objections, which has been raised against the simultaneous method, is that vaccinated animals excrete the virus, sometimes for long periods (the so-called "carrier" state) and that a proportion of them become wasters. Opinions differ somewhat as to the magnitude of this risk. For instance, Geiger considers that the risk is slight and in any case much less than with the natural disease. Gerlach (Ref. 10), however, has recently reported that he has found virus for as long as 10 months in the lymphatic glands of roughly three-fourths of vaccinated animals. This has not been confirmed. A further objection raised is that, since a strong virus is regarded as essential for successful immunisation, the process of vaccination may implant a strong virus in regions where a weak virus existed previously.

Consequent upon the report of Professor Hutyra, to which reference has been made above, the Council of the International Office for Epizootic Diseases in 1931 (Ref. 10) adopted the following resolutions :—

1. In countries where only isolated outbreaks of swine fever occur, the disease may be suppressed by police measures associated with immediate or deferred slaughter.

2. In heavily infected districts, especially in those with a large swine population, where the difficulties of carrying out this procedure would be insurmountable, police control should be supplemented by passive (*i.e.* serum) immunisation.

3. Active (*i.e.* serum plus virus) immunisation may be recommended in serious outbreaks, provided the virus used is obtained from the same locality. If these conditions are not observed, simultaneous vaccination is not without danger, since it introduces a very active virus which may be harboured for a long time in the bodies of the vaccinated animals. The procedure should only be carried out under the supervision of the veterinary health services.

4. Pigs, which have recovered from swine fever, have to be considered dangerous for an undetermined length of time, and such animals should remain under sanitary supervision until slaughtered.

5. Experimental research should be continued with the object of obtaining a vaccine of constant strength and, also, with a view to determining the factors which are responsible for the very variable susceptibility of pigs to the virus.

III.—INTESTINAL DISORDERS IN CALVES.

The present article is not intended to be in any way comprehensive, and space does not permit reference to such important intestinal diseases of calves and young cattle as those caused by worm parasites or the so-called coccidia. The subject has been selected for consideration mainly with the object of presenting new knowledge which has been gained during 1931, but, owing to the importance of calf diseases to the dairy farmer, the opportunity has been taken to describe some of the less recent work, of which no account has yet appeared in these volumes.

White Scours or Infectious Diarrhoea.

This condition is very prevalent among calves and its general characters are so well known to owners of dairy stock that a lengthy description of the symptoms and course can be omitted. The disease makes its appearance within the first few days after birth, the outstanding symptom being diarrhoea, with whitish or clay-coloured and very fluid faeces. The animals refuse food, show signs of great depression and death takes place during the first 8 or 10 days. The disease is not always so acute as this, however, and death may be delayed beyond this time, or the animals may eventually recover. In these less severe cases the diarrhoea is more intermittent in character, but other complications are likely to appear,

such as swelling of certain joints (joint-ill), inflammation and abscesses about the navel (navel-ill), pneumonia, and the animal remains for some time in poor condition. The evidence suggests that the disease is infectious, since similar symptoms are frequently observed among groups of calves kept under the same conditions.

It was ascertained some years ago that white scours is a bacterial disease and that the micro-organisms most commonly present belong to the *B. coli* group. *B. coli* is not, however, a disease-producing organism in the ordinary sense, that is to say its presence in the body by no means invariably produces disease. Members of this bacterial group are widely distributed in nature and among other situations they are constantly present as harmless inhabitants of the digestive tract of cattle. It is clear, therefore, that the mere presence of *B. coli* in the intestine of calves is insufficient to account for the severe effects it sometimes produces. The bacteriological researches of Theobald Smith and M. A. Orcutt in the United States, reported in 1925 (Ref. 12), have thrown a good deal of light upon the sequence of events in the body of the calf destined to fall a victim to white scours, and have done much to explain how bacteria which are harmless for adult cattle and for calves which have survived the first few weeks of life, are able to produce disease in very young calves. *B. coli* is normally present in the intestine of the young calf, frequently in small numbers only, but should any failure of the digestive functions arise at this critical period of life, immediately after birth, the organisms increase in numbers, especially towards the lower end of the small intestine. If this abnormal condition is not rapidly corrected, the numbers continue to increase and the animal may then be said to have passed into a state of disease. In fact, it has been stated that if *B. coli* multiplies freely during the first 48 hours after birth, the calf is doomed. In the more advanced stages of the disease, microscopic examination of the lining of the intestinal tube shows that in places it is covered with masses of *B. coli*, and these organisms are also abundant in all parts of the small intestine. It is this excessive multiplication, accompanied by a liberation of bacterial poisons, which is responsible for the diarrhoea and general state of intoxication. Coincident with the rapid multiplication of *B. coli* in the intestine, the organisms invade the internal organs of the body, *e.g.* liver, lung, kidney, etc., and produce what is called a septicaemic condition. This is the sequence of events in the more acute forms of the disease. It is not all cases of white scours, however, which progress at this rapid pace. In certain conditions, referred to later, the animal's body is endowed with greater resistance, so that

the bacteria are to some extent held in check. In this case they remain confined to the intestinal canal, or they reach the internal organs in small numbers only and give rise to the complications mentioned earlier, *viz.* pneumonia, joint-ill, navel-ill, or disease of the kidneys. Such animals may succumb after a few weeks or survive, with or without passing through a stage of unthriftiness.

The Importance of Colostrum.—From what has just been said it is apparent that a disturbance in the mechanism of digestion is one of the chief contributing causes of white scours, and it is now widely recognised that the risk of such disturbance is enormously reduced if nothing happens to prevent the young animal obtaining the milk first secreted after calving, the so-called " colostrum " or " biestings." The necessity of feeding colostrum has been referred to by J. Macintosh (Ref. 13) in a previous volume of this series. As stated in that article, colostrum differs from ordinary milk in being very rich in certain proteins and in containing large quantities of substances (so-called " antibodies "), which are antagonistic to bacteria and their products, and which are necessary for the protection of the intestine of the newly-born calf. It has also been considered that colostrum has a purgative action in causing evacuation of foetal fluids and solids from the intestinal tract, but it is improbable that this is as important as the protective effect. In any case it is certain that neither milk which has been boiled nor even raw milk can replace colostrum in the diet of the new-born calf.

It is useful here to recall the striking results obtained in the United States, in 1922, by Theobald Smith and R. B. Little (Ref. 14), who were the first to demonstrate in properly controlled experiments the evil effects which follow the withholding of colostrum. In these investigations, 12 calves from the same large herd were removed from their mothers at birth and immediately conveyed to a Research Station 1½ miles distant. During this time they were protected against undue exposure, and on arrival at the Station they were thoroughly dried with warm towels and each was placed in a separate heated stall. The calves selected were known to have had no opportunity of suckling their dams and they were subsequently fed on fresh raw milk in place of colostrum. Of the twelve calves seven died within 6 days, one was killed when moribund on the fourth day and one died on the eleventh day; in all cases *B. coli* had multiplied in the internal organs. Of the three remaining, one which had shown joint affections due to *B. coli* was killed on the twenty-seventh day; the other two survived and thrived normally until slaughtered at just over two months of age. In order to control these results, ten

calves from the same farm were treated in exactly the same way except that they were allowed their normal intake of colostrum. All of these survived what is recognised to be the danger period in scours, but three died unexpectedly 25, 38 and 45 days later. Death was attributed to some kind of poison, and was certainly not due to any ordinary affection, and *B. coli* could not be cultivated from the organs.

As stated previously, the main function of colostrum is probably a protective one, and this being so, it should be possible to replace colostrum by the "serum" which exudes from shed blood after clotting, since this fluid is also rich in protein and contains antibodies. The point is not without its practical significance, since there may be occasions when it is not desirable that the calf should get its mother's colostrum, *e.g.* in cases where tuberculosis of the udder is suspected, or where the colostrum of no other cow is available. Moreover, there need be no great difficulty in obtaining a supply of serum. The question of giving blood-serum to new-born calves has also been subjected to experiments by Smith and Little (Ref. 15). In these experiments, three groups of newly-born calves, five in each group, were fed with the raw milk from three cows in mid-lactation in place of colostrum, and were also given blood-serum in various ways. In the first group, as soon as possible after birth, 20 c.c. serum (rather less than half an ounce) were injected into the veins and 20 c.c. beneath the skin; next day 20 c.c. serum were again injected beneath the skin. The result was unsatisfactory in that three of the animals died of white scours and the other two were temporarily ill but recovered. The serum, however, had afforded partial protection, because in the dead calves invasion of the internal organs by *B. coli* had not occurred, except slightly in one case. In the second group, 100 c.c. serum was mixed with the milk at each of the first two meals, with the result that three of the five calves survived. It should be said, however, that one of the two which died was weakly from the start, and that in both the fatal cases the serum had prevented *B. coli* penetrating their internal organs. The best results of all were obtained in the third group, in which each calf received 60 c.c. serum mixed with the milk in each of the first two meals and was also injected with serum as soon as possible after birth, 20 c.c. being given into the veins and 20 c.c. beneath the skin. In this group three of the calves remained quite healthy, while the remaining two got slight diarrhoea which soon disappeared. In order to control this work, an attempt was made, at the same time, to bring up two calves without either colostrum or serum, but both these animals died in two days of *B. coli* septicaemia. Smith and Little conclude that, if serum

is given in sufficient amount and in the proper way, it can replace colostrum in nine cases out of ten and with no injury to the calf, although serum is nothing like as efficient a protective as colostrum.

Prevention.—In a general way, the solution of the problem of prevention lies in proper feeding and good hygienic conditions. In the past, great stress has been laid on the necessity for clean surroundings, isolation, disinfection, and proper attention to the navel immediately after birth. These points are important, and in addition, cold, wet, dark and poorly-ventilated pens are certainly to be avoided. The use in prevention and treatment of "specific" serum has also been recommended, that is blood-serum from an animal whose resistance has been raised to a high pitch by injecting it repeatedly with cultures of *B. coli*. As to disease prevention, there is much to be said for the practice of removing calves from their dams immediately after birth and rearing them in crates or in properly cleaned and isolated stalls. If this cannot be done, it is a good plan to muzzle them at times when they are not taking food. The importance of proper feeding with colostrum has been well demonstrated by the experiments referred to above. The first meal of this protective fluid should be given as soon as possible after birth, if necessary from a feeding bottle. When it is suspected that the dam's udder contains disease organisms, *e.g.* tubercle bacilli, cow serum may be given instead. In this case some 600 c.c. (about one pint), or better perhaps 1,200–1,500 c.c. may be given mixed with raw milk, and the results will be still better if two or three injections of half an ounce of serum are given under the skin during the first 24 hours.

It is by no means claimed that all calves will survive, even when fed with colostrum, for it is known that white scours sometimes prevails in spite of normal feeding at birth. Several reasons can be assigned for this. In the first place, the calves may be getting insufficient amounts of colostrum, or, perhaps owing to some delay in feeding, they may be tempted to consume excessive amounts at one meal. In the latter case, not only does the delay give *B. coli* a chance of getting a foothold, but its multiplication is favoured by the digestive upset arising from over-distension of the stomach due to the overdose of colostrum. In the second place, although proper amounts of colostrum are taken, the animals may die because the prevailing form of white scours happens to be very acute. In the experiments of Smith and Orcutt it so happened that the white scours infection prevalent at the time was not highly acute in character, otherwise the results would probably have been less striking. Their work, however, also showed that

quantities of colostrum which fall short of being entirely adequate, may prevent the rapid infection of the internal organs by *B. coli*. This partial protection may be of value in practice in saving calf life, in circumstances where the white scours infection is rather mild in character.

In considering the problem of prevention of any disease, it is usually essential that its nature should be understood, and that is why the experiments of Theobald Smith and his colleague have been described. This work goes a long way to explain many of the mysteries of white scours, in particular it explains how the condition arises and why the disease may appear when there is no evidence of introduction of infection from without. It also shows that all attempts at prevention, based solely on keeping the invading bacteria away, must be inadequate, because these organisms live in the normal cow and are present in its surroundings. In order to explain persistent outbreaks of white scours, one must assume both inadequate digestive functions and increasing power of *B. coli* to produce disease. These two factors will react upon one another, since the failure of the normal digestive function will lead, as explained above, to abnormal multiplication of *B. coli*, and, especially where calves are overcrowded, this will facilitate their rapid transfer from animal to animal, a process which is recognised to bring about an increase in the infecting power of bacteria. The same process will tend to create special strains or races of *B. coli* and, unfortunately, it is improbable that these will be effectually countered by treatment with specific serum, unless the serum has been prepared against the particular races of *B. coli* which are causing the outbreak.

Vibrionic Enteritis.

This name implies an inflammatory condition of the intestine caused by bacteria, which are known as "vibrios." Whereas many bacteria when seen under the microscope appear in the form of straight rods, vibrios are curved, mobile rods resembling commas or short spirals. One of the best known of this class of organism is that which causes cholera in human beings; in animal pathology certain vibrios are also known to cause disease, an example of which is a particular form of abortion in sheep and cattle. During 1931 Jones and Little (Ref. 16) in the United States discovered an intestinal disease of adult cattle and calves, which they consider is caused by vibrios, and it is the purpose of what follows to describe briefly their findings.

In certain dairying districts in the United States, there had been noticed among cows outbreaks of severe diarrhoea. Since these outbreaks occurred during the autumn and winter, the

disease has been referred to as "winter scours" or "winter dysentery" and since one of the chief symptoms is the evacuation of dark brown or blackish liquid faeces it has also been called "black scours." Until the present work was carried out, the cause of the disease was obscure, and dietary factors, especially the feeding of ensilage, had been assumed. In the conditions as observed by Jones and Little, in which 400 cows in 5 herds were affected, dietary factors could be definitely ruled out. The features of the disease were as follows. The onset was sudden; at first a few cows were noticed to be scouring, but cases of diarrhoea followed in rapid succession in the particular group, or even affected every animal in the herd. The diarrhoea lasted for a few hours or for as long as four or five days, after which the condition improved. In certain instances recovery was only temporary and the diarrhoea returned when the animals were put back on to normal diet. There was very little fever, but the breathing was often noticed to be rapid. The faeces were sometimes foetid, deep brown or greenish-black in colour and often contained blood or slimy material. There was much loss of milk production and in the worst cases the animals were dull and showed signs of abdominal pain. Deaths were not common, but if an animal was killed for post-mortem examination the small intestine was found to be inflamed in its middle and lower parts and there were slight degenerative changes in the liver.

In endeavouring to establish the cause of this condition, Jones and Little fed three normal calves with suspension of faeces from spontaneous cases in cows. This produced in all three animals a definite reaction, which was similar to that seen in the cows except that it was milder. One of the calves suffered from diarrhoea which lasted for 2 days and reappeared 7 and 14 days later. In two cases the faeces were soft and foetid, and in the faeces of the third there was a lot of slimy purulent material. The calves were killed 5, 12 and 16 days after feeding; post-mortem examination showed inflammation of the intestine and from the mucous membrane of the parts involved tiny, motile vibrios were cultivated by means of rather special methods. The proof that these vibrios were the cause of the disease was established more firmly by further experiments, in which three calves and a young cow were fed with pure cultures of these organisms. As a result, the three calves developed signs of enteritis, *viz.*, diarrhoea or the evacuation of slimy purulent material, while the young cow showed diarrhoea, with blood-stained slime in the faeces, and the milk yield stopped almost completely. From this cow and two of the calves vibrios were again recovered; and in fact throughout this work these were the only bacteria

to which any significance could be attached. The inflammation is usually found to be most prominent in the middle portion of the small intestine, in the part which is called the jejunum, and for this reason it is suggested that the organism should receive the name of *Vibrio jejuni*.

In a later paper Jones and Little (Ref. 17) give an account of this vibrionic disease, as it occurs in calves. In one large herd many calves between the ages of one and two months had been slaughtered shortly before on account of the disease. Most of the cases were in calves over two weeks old, the disease being more or less chronic, and the animals showing unthriftiness with distension of the abdomen and diarrhoea. Towards the close of the years 1929 and 1930, only isolated cases were observed among the older calves in a large dairy herd, but with the onset of colder weather the disease assumed the form of an outbreak and was largely responsible for the death or slaughter of many calves. The faeces in these cases were soft or gummy in consistence, varied from clay-coloured to dark brown and frequently contained blood and slime. A few older calves suffering in this way were allowed to mix with young and vigorous 6 to 8-day old calves, with the result that the latter became infected. This suggests that in the field, infection occurs quite early in life and that the disease is introduced into herds by the exposure of young, susceptible calves. In such animals for a time the reaction remains quite mild, clinical symptoms becoming pronounced only when the disease passes into a more chronic stage.

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I.—General Introduction.

In the literature of agricultural economics the results of research, inferences from these results, suggestions from general economic reasoning, and general truisms get mixed together. The actual results of research may be distinguished, but close attention is often needed before the character of other statements can be determined. Results of research should be and are definite, but they are often definite only for a restricted area or period of time. The inferences from results may be limited to the field which has been covered by the research, or they may be carried far outside. In some cases the extension of inferences may be perfectly justified, but in others it is to be viewed with caution. Suggestions or conclusions from general economic experience are sometimes necessary, and always useful, but they provide only very general guides to economic activities. The truisms or platitudes of economics, even agricultural economics, sometimes embody the gist of a hard-gathered wisdom but equally often conceal a lack of critical analysis. Their apparent strength is in their generality and dogmatism, their real weakness in their inapplicability to individual cases as they occur in practice. But all these forms of statement are useful, and none is entirely to be neglected.

Economics necessarily takes to itself some colouring from contemporary business and political conditions and thought, and agricultural economics is susceptible to this deflection. We do not yet know what is fundamental, or what is fixed, in the economic systems and conditions under which British agriculture is organised. Nor perhaps shall we ever know until or unless the nation determines certain purposes and conditions as those necessary to maintain. Even then we will never be

able to stop the whole flux in economic conditions and forms of organisation. But in considering the results of research in agricultural economics it is very necessary to remember that in the main they deal with recent history, and with historical conditions which may not be exactly repeated immediately even if they ever recur.

Changes in the general price level, changes in relative prices of commodities whether raw materials or products, changes in demand, and changes in equipment or materials for production will occur over short periods of time and any one may invalidate the future application of results of some research. The main results of economic research which are stated in cash values are peculiarly liable to require modification when used for future guidance even if they are not invalidated. Where any conditions are fixed, or are exactly repeated, the exact knowledge of conditions or forces and results is a reliable guide for future action. How much of the fruits of research into conditions, forces and results of the period since 1924 will be useful for the future it is almost impossible to say, but some will yet be of practical value. The attempt is made to read the past and the present, to distinguish and describe with the greatest accuracy the conditions which are found, to discover relations of the nature of causes and effects, and to measure causes and effects as nearly as possible. On this basis attempts may be made to get a clear view of the probability of recurrence of the same conditions or the possibility of modifications, and to obtain some guides to action.

This "shifting of the economic scenery," and the tendency to colouration of general economic views by current political and social conditions, may make the results of research less certain in economics than in some other agricultural sciences, but it makes the research itself all the more necessary. Changes in the economic scene are particularly important in respect of some market conditions and marketing studies. Variations in demand for types and qualities of livestock, changes in consumers' demands for final products, and in the relative prices and values of different products, need constant analysis, for here nothing is quite fixed. But any one of these changes may bring or require changes in farm organisation and operation, and though there are "lags" between changes in market conditions and those in farm management the flux is there all the same.

There is, however, one other point necessary to bear in mind in connection with the results of research in agricultural economics. Investigations of current conditions are directed to discovery of weaknesses which are manifested in the economic sphere—generally in cash results—but in part these weaknesses

may be technical in their origin. For instance, if the accounts of a farm show loss or very small profits and the further analysis indicates that the dairy herd is the source, then still further analysis may show that the essential weakness is in over-feeding, under-feeding, or general poor rationing or breeding of the herd. Or, again, when poor results are found on another type of farm, the cause may be discovered in a sheep flock and on close analysis may be found in high death-rate due to disease. The point of the economic analysis in such cases is that it locates the weakness, but the remedy for the cause will be technical in character. These are simple illustrations. In a more general way the economist will say that he deals with the normal technical practices and conditions and where his results are of mass character they take into account at least all the common variations from the norm of a given area or time. Doubtless this tends to be true, but the exposure of the economic effects of both the normal and variants therefrom in such conditions as the occurrence of abortion or the general rate of depreciation in dairy cattle, or the occurrence of some of the more obscure causes of losses in sheep flocks, should lead to efforts towards individual and general control. There is, however, another aspect of the description or measurement of the normal and the variants. Where market demands or relative prices have changed, or where there are possibilities of change in farm equipment or in raw materials, variations from the normal shown in adaptation of farm practices to the new conditions may or may not show the way towards a new normal. To them also the economic test should be applied. So that even in economics the individual should not be smothered entirely in the mass.

These general considerations, and others, arise from the perusal of the literature of research in agricultural economics in 1931.

II.—Prices.

Amongst other matters considered in relation to prices and agricultural prosperity in recent years the supply of money and credit is not of least importance. Here there is little to report as a result of research of the more formal and elaborate character, yet appreciation of the relation of the agricultural price level to the general has been carried a stage further. The prices of commodities are all measured in a single commodity —gold (or the credit system based upon it). It is a mistake to assume that the future price level for wheat is a problem in the supply and demand for wheat itself. It is a problem of supply and demand for wheat only if the gold price level is stable ; but if not, it is primarily a currency problem and if a long period view is taken, it is essentially the latter aspect that is important

(Ref. 1). From 1925 onwards one country after another returned to gold, and, owing chiefly to War Debts and Reparations, gold accumulated in the United States and France. Elsewhere the demand for gold increased and the free supply diminished with a consequent appreciation in value and a long time fall in prices of commodities was initiated. The fall was comparatively slow until 1930, when a combination of factors produced a sudden slump beginning in the United States with a collapse of the Stock Exchange in 1929. Improved technical methods and a slackening of demand caused glut of some primary products, pushing prices down still further. In particular, agriculture, in nearly all countries, became depressed, wheat suffering a specially great fall in price. Producers of primary commodities lost purchasing power and world trade diminished. The situation up to the end of 1931 was that cereals had fallen in price more than the average of wholesale commodities, livestock products less. Corn-growing has been essentially an unsheltered trade, exposed to the full blast of competition; meat producers enjoyed some differential advantages; fresh milk was a sheltered product save for the competition of its dried and condensed forms (Ref. 2).

Wheat growing is one of the enterprises in which changes in technique have added to the general tendency to reduction of prices by reducing the costs of some producers (Ref. 1). Abroad new kinds of grain have increased the area of potential wheat lands; new machinery has reduced the amount of labour required. Wheat growing has been permanently cheapened in some areas (Ref. 2).

Again, it is at least suggested that wheat illustrates one general but somewhat simple principle of supply and demand in the markets for foodstuffs. If the efficiency of producing grain is greatly increased and greatly cheapens its price, the consumption of grain cannot be increased in anything like the same proportions as would be the case with some other commodities. The demand for food does not vary very much with the cheapening of food. The human stomach is limited to about 3,000 calories of food a day; if this is obtained in one way more is not required, however cheap food may be. Sales of other commodities are much more affected by price than are sales of agricultural products. Thus, demand being inelastic, the price received for farm produce is disproportionately affected by the supply (Ref. 1). Owing to a decrease in consumption and an accumulation of stocks, for the time there is a glut of grain (Refs. 2 and 3).

While the statement of this simple and general principle is useful the analysis requires to be pressed much further. Many important changes in consumption have occurred, especially

in times of rising incomes amongst the general population; and some changes may be expected whenever general incomes rise or fall. During the period 1880–1925, while incomes were on the whole rising, and especially when foodstuffs were relatively cheap, the general direction of change was towards increased demand for foods of animal origin and more or less generally towards the more expensive types. At present it appears impossible to estimate at all exactly the effect of these changes in demand on the amounts of farming capital and labour required to produce the total food requirements of a given number of persons. Yet it is quite clear that where demand changes towards more expensive foodstuffs with a higher total expenditure on foods, even though there is no increase in quantitative consumption per head, more labour and capital may be required than previously to feed the people. There is a sort of race between rising technical and economic efficiency in production, the growth of population, rising or falling incomes and changes in the total amounts of money which the people spend, or can spend, on foods. During recent years there is no doubt that gluts have been due to lack of purchasing power as well as to what would be accurately described as over-production. Here, obviously, is an open field for research which may be of great importance to agriculture.

The most important results of price studies yet published in full are those of Murray which deserve more attention than is possible in a short review. Very little relation was found between the supply and purchasing power (that is the price of one commodity relative to the general level of commodities) of beef. The demand as represented by the purchasing power of wages (real wages), was about five times more important in the determination of the purchasing power of fat cattle than the supply. Any hopes of higher prices of fat cattle based merely upon expectation of shortages of supply, without reference to the trend of real wages, would be likely to be illusory. There is a fairly close relationship between the number of sheep in Great Britain at any time and the purchasing power of prime mutton, but the demand is of greater importance than the supply in determining the purchasing power of inferior qualities. Imports of pork being small, the number of pigs in Great Britain is the most important factor in determining the purchasing power of pork; and even in determining that of bacon, imports of which are large, the home-produced supply is more effective than the quantities imported. There is no evidence of cyclical fluctuations in production of cattle in Great Britain, but there are definite cyclical fluctuations in the numbers of sheep and pigs. The cycle of sheep production varies from six to nine years, the

more recent cycles lasting about nine. Before 1904 the cycle of pig production was from five to six years, but since that time it has become shorter and now varies between three and four years (Ref. 4). The possibility of increased demand for meat with increased purchasing power in the general population was emphasised by consumption figures which showed that as incomes increased there was a greater *per capita* consumption and also a tendency to buy dearer cuts and joints. From a study of working class budgets it was estimated that the percentage of total family expenditure devoted to purchase of meat rose from 12·5 in 1887 to about 17·2 in 1900, and to 19 in 1918. But consumption of meat by weight increased only 22 per cent. or, as estimated, from 108 lbs. to 132¾ lbs. per head.

Each "market" has its own peculiarities. When prices of fat sheep or wholesale prices of dressed mutton begin to fall, the prices of inferior qualities fall faster than those of superior qualities. And when prices of mutton in general begin to rise, the prices of inferior qualities tend to rise faster than those of superior. A shortage of home-produced mutton and lamb has a greater effect in driving up prices than an excess in the supply has in driving them down. This is more marked in the case of superior than in the case of inferior qualities. There is a fairly fixed demand for lamb and prime mutton which must be met as far as possible when supplies are short. Then when supplies increase the home produce tends to press heavily on the market for imported mutton and lamb (Refs. 4 and 5). Such are the tendencies found during a period in which, on the whole, the spending power of the general population was rising. There are already indications that a tendency towards relatively high consumption of beef may occur with a lower spending power in the general population.

III.—Consumers' Preferences and Demand.

Investigations of conditions of demand for farm products are in their early stages, nevertheless important contributions to knowledge are being made. A study of meat consumption in Loughborough revealed that less than 10 per cent. of households preferred "fat" joints, about 27 preferred "lean"; and about 63 per cent. the "medium" type; and there was little significant difference between summer and winter. Only about 5 per cent. preferred the "large" and about 26 per cent. the "medium" joint, while nearly 69 per cent. of households preferred the "small" sized joint during the summer. Rather surprisingly the percentage of families preferring the "medium" sized joint rose in summer, while the proportion preferring the

"small" size fell. Consumers' preferences for lean meat and small joints are not the expression of seasonal caprice. Dividing consumers into a "well-to-do" and a "labouring" group, the former were found to consume over 2 lbs. of meat, the latter little over 1½ lbs. per head in one week in winter. These figures showing purchases of kinds of meat, home produced and imported, are worth quoting in full.

	Percentage of total consumption. Well-to-do.	Labouring.
Home-killed pork . . .	10·0	8·4
,, mutton and lamb .	28·8	14·5
,, beef . . .	46·4	41·0
Imported mutton and lamb .	6·8	10·8
,, beef . . .	0·37	22·3

The figures for home-killed mutton and lamb and for imported beef are very significant. The elasticity of demand for meat is shown in more detail by grouping consumers on an income basis. Lower consumption as lower income groups are traversed indicates the possibility of increasing consumption appreciably by reduced retail prices (when margins tend to be wide). The influence of consumers' preferences on farm prices is shown by the fact that the final demand for small and lean joints has a strong influence on the price per live cwt. realised by different classes of fat cattle. The evidence of relation between consumers' demand and liveweight prices of fat sheep and pigs is not so direct as these animals are not normally sold on a weight basis, but the indirect evidence of preference and stronger demand is clear (Ref. 6).

This study, however, emphasises the variations in demand for different purposes. In this area of Leicestershire, while the domestic preference for small joints is marked, there is a market for large, well-finished cattle due in part to the steady demand for large joints in hotels, restaurants, and similar institutions and in part to the requirements of country districts. The latter source of this demand rather indicates that the tendency to prefer the small and lean joint arises from conditions of living in towns, but whether these are such as may spread to rural districts is unknown (Ref. 7).

A study of cattle feeding in the Midlands suggested that the influence of the change in domestic demand for small joints on the general market for fat stock has been overemphasised, and that a specialised demand for the larger store cattle and the larger beef carcases still exists (Ref. 7).

Some further work by the Empire Marketing Board indicates that there may be very practical commercial results from the study of consumers' demands in this country.

IV.—Marketing Farm Produce.

The Report on the Organisation of Potato Marketing marks a new stage in the development of the "Orange Series" of marketing studies issued by the Ministry of Agriculture. Although this contains descriptive and analytical materials, its main purpose is the consideration of schemes of marketing organisation. Figures show that any upward or downward change from the mean annual supply is generally accompanied by a considerably wider variation from the mean price in the opposite direction. On actual prices of 1925 when the supply was 14 per cent. below, the price was 46 per cent. above normal. In 1929–30 when the supply was 16 per cent. above normal the price was 44 per cent. below. It is likely that more potatoes are consumed when they are cheap than when they are dear, but, owing to the inelasticity of demand the amount of potatoes consumed in glut years is still considerably less than supplies available in spite of the low prices which then prevail. There is a definite limit to the quantity of potatoes which will be purchased for human consumption. This limit is in the neighbourhood of 4 million tons, and when supplies exceed this figure the market is faced with the "surplus" problem. Surpluses cannot be prevented, being due more to variations in yield than to those in acreage, so the marketing system must be organised to prevent them spoiling the market. Greater stability in prices would tend to reduce the variations in acreage planted, and, it is suggested, possibly to encourage greater consumption. Suggestions for the regulation of marketing are given in detail (Ref. 25).

A report on the Marketing of Honey and Beeswax providing information on supplies, demand and prices, describing the general methods of marketing and making suggestions for improvement, should be of great interest to bee-keepers (Ref. 23). The report on Preparation of Fruit for Market sets out in detail for guidance of growers and packers the best commercial practices in the preparation for market of the small fruits (berries), with tomatoes, cucumbers and grapes (Ref. 22).

The report on Marketing of Mutton and Lamb is the most important of the Orange Series from the point of view of economic description and general analysis. There has been gradual encroachment of the imported frozen mutton and lamb upon the home market, but the best class trade is still met by home-killed supplies. Overseas producers supply nearly 60 per cent. of total consumption as compared with 45 per cent. 30 years ago. In exporting countries there has been a gradual change of objective in sheep production from wool to mutton ; improvements have been made in the methods of handling and freezing,

and other improvements expected in refrigeration may intensify competition. The proportion of inferior kinds of mutton and lamb produced in Great Britain is commendably low—lower, for example, than in the case of beef. There has been a heavy decline in the number of fat sheep marketed at one year old and over, the proportion of this type falling from about 26 to about 8 per cent. in between the pre-war years and 1923–29, but "hoggets and fed lambs," *i.e.* usually over six and under twelve months, have increased from 46 to 64 per cent. of total carcases; fat ewes and "milk-fed lambs" remain at about the same proportions. This denotes a very considerable change in farm practice towards the earlier marketing of lambs. But there has also been a large increase in the proportion of imports sold as "lamb." In the sale of imported supplies everything possible is done to simplify the task of the wholesaler, retailer, and consumer in ordering and handling, and to inspire confidence in the product. Increasing intensity of competition makes it essential that the advantages of the home product should be brought forward and exploited to the utmost. Therefore, grading of carcases, the use of the National Mark, and advertising are suggested. The facilities for slaughtering and dressing, on the whole, leave much to be desired, and the concentration of slaughtering into fewer and better equipped units should secure for the home industry the economies and efficiency enjoyed by overseas competitors, and facilitate the work of selling agencies (Ref. 24).

V.—Farm Organisation.

In farm organisation and operation one of the most important factors is the choice of the form of labour-power and the relative costs and results of labour and power in different forms. And from the choice of the form and source of power flow very important results, not only in the individual enterprise, but in society at large. Here, indeed, are some of the closest of the relations between the individual farm and general social conditions. The most important survey of the influence of machinery and inanimate power on farm organisation comes from Canada, and is partly of the nature of research and partly of that of compendium (Ref. 8). Taking the United States as a whole, it is stated, the efficiency of the average farm worker was nearly 86 per cent. greater in 1900 than in the year 1870. Although the total population in 1927 was a little more than five times as great as in 1850, and although the acreage of improved land had increased about four and a half times during the same period, yet the number of agricultural workers was a little less than three times greater. In Canada the value of machinery per acre has

risen from about 7*s.* in 1901 to 19*s.* 8*d.* in 1921 ; acres of improved land per man rose from 42 to nearly 68 ; and crop acres from about 28 to nearly 48. The process has continued since 1921. Progress of mechanised farming is shown by tractor sales in Western Canada, which amounted to about 10,000 in 1920, ranged between 2,000 and 6,000 in the period 1921–26, and rose to 17,000 in 1928. Numbers of tractors produced in factories about doubled in five years. Sales of "Combines" (harvester-threshers) in Western Canada rose from 176 in 1926 to 3,657 in 1928 and then fell off to some extent. Mechanisation puts the small farm at a relative disadvantage. Of farms of less than 160 acres in Western Canada one in seven was abandoned ; of 161–480 acres one in twenty-five, of farms of over 481 acres only one in one hundred. (In passing it may be remarked that one advantage of the resistance to change of an old-established and multiple-enterprise system of farming is that land is not so frequently entirely abandoned in periods of depression.) A study of tractor, machine and implement costs in great detail deserves the attention of those specially interested. Some conclusions may be stated in general form. Machinery not only makes it possible for the farmer to handle more land, but makes the necessity of increasing acreage in order to secure the most economical use by reducing overhead costs per acre. There must be available the minimum amount of work which will enable the machine to repay capital investment and cost of maintenance over a reasonable period of time. The individual operator considering purchase of equipment must take into account the nature of land, size of fields, existing acreages of crops, and possibilities of expansion or contraction. Full economy in use of one machine may require changes in others used in a combination of processes. Small units of equipment are more profitable where wages are low, and large units where high rates are paid. Under ordinary conditions the saving of labour will more than equal the extra cost of power and machinery, but there is a limit beyond which this does not remain true.

The influences of machinery on times of conducting operations, yields, and quality of product are dealt with ; but there is yet little of clear evidence on some of these points.

An important suggestion is that in the recent process of mechanisation in agriculture the major ideas and efforts of inventors, adaptors and manufacturers have been directed towards production of units for relatively large-scale agriculture, or have brought forward equipment more suited to that type. There is room for more thorough study of small-scale farming technique and the consideration of needs by which the equipment suitable for small-scale production may be developed and

made as efficient as already provided for large-scale organisation. While there is physical economy in the use of relatively large-scale power units and machines, this is checked on the cash side by consideration of capital charges spread over the period of work.

This study links up with work by Orwin (Ref. 9) in suggesting the influences of mechanisation on general management. Large-scale farmers in some areas show more care in financial matters, and tend to accumulate reserves to secure their position. They also tend more towards specialising management, employing workers of specialised ability and training. In marketing and general business the larger operators have demonstrated superior skill.

Orwin's studies of changes in farm equipment and management which are under consideration for 1931 are descriptive rather than analytical, but for their special purposes perhaps all the more valuable even though they do not lend themselves to easy condensation. In the case of Mr. Hosier's system of dairying he shows how the buildings and fences were adapted, how water was laid on, how the "dead stock" equipment was changed; how the labour is organised and used, and finally the general system of management. And to this is added a description of much the same items on the additional arable farm. Here tractor costs of ploughing and planting oats are given as 12*s.* 3*d.* an acre, and the costs of *ploughing only* by horses as 12*s.* 8*d.* The costs of milk production for 1923–24 and the following three years were all between 7·2*d.* and 8·8*d.* per gallon. Labour costs were less than one-half those recorded for either the Oxford or the South-Eastern Provinces at the same period, and bulk foods cost less than one-third of the amounts recorded in those Provinces.

This is essentially a study of an individual case of adaptation to economic conditions, some perhaps local and temporary but also some which are general and apparently continuing. Mr. Hosier should be regarded as a specialist in farm management. The principles behind his systems and all the details of equipment and organisation are organisation on a large scale, specialisation in production, mechanisation of farming processes, and elimination of waste. It is said in this case that the system of farming followed is flexible and could be adapted to changes in the markets because it is highly specialised. But the general *dictum* that "flexibility in farming demands a high degree of specialisation" needs checking with reference to other conditions. The strength of the position of the large and specialised producer in the market is noted in this case (Ref. 9).

The three principles suggested as fundamental to the success of the capitalist farmer to-day—operations on a greater scale,

more mechanization of labour, and a greater degree of specialisation—are further illustrated by the study of a farm on Hayling Island operated by Mr. A. H. Brown. This is a case of "high farming," with cows, poultry, some pigs, and crops. Sales in 1930–31, the highest ever recorded despite the fall in prices, exceeded £10,000 or some £21 per acre; and represented a turnover of capital of 143 per cent. The output per man employed, after deducting estate labour, exceeded £570. The "old-fashioned mixed-farming rotation is thrown to the winds." Corn-growing, milk production, egg production are each highly specialised enterprises, carried on separately with little or no interchange of labour. Rates of wages paid are higher than customary in the district. The emphasis in this study is laid on organisation as a factor in success, and there is special consideration of organisation and management as checks on the working of the law of diminishing returns in intensive production. The use of machinery, the position and shape of the arable fields, the system of cropping and the cost of farmyard manure, all these and other things are, to a certain measure, within the farmers' control in the influence they may exert upon production costs, and the total which they may represent may be moved upwards or downwards according as the management is active and mobile or passive and static. Efficiency of organisation may set back the point at which diminishing returns begin to occur in the high or higher production. Although only indirect evidence of the profitableness of this farm is provided, there is general assurance that high profits have been earned (Ref. 10).

A close study of the relations between farm incomes and standards of production on Welsh farms showed that (1) the higher outputs tend to be associated with the higher earnings when incomes are stated as percentage returns on capital, and a closer association between output and earnings when incomes are measured per acre; (2) a fairly close association between income and capital per acre, but a lower degree of association between capital per acre and income measured as percentage of capital; (3) a very close association between standard of production as measured by either sales or output and the rent per acre; (4) again a very close association between capital and output, but (5) a fairly low degree of association between value of output and amount of labour used. In general as might perhaps be expected, higher rentals and higher capitalisation are associated with the higher outputs and these are associated with the higher profits or earnings. But it is not quite enough merely to say that the farmer on the better land produces more and earns more than the farmer on the poorer land, as on each grade of land the higher standards of production

up to the optimum yield the higher returns. Finally, there was no indication that the farmers concerned would be well advised to reduce their outputs or to lower their standards of farming in the period dealt with (1929–30). On the contrary, the indications were that in general some increases in production would bring higher earnings, certainly higher earnings per acre, and in most cases higher gross profits as per cent. of capital. This study necessarily dealt with farms of existing types and sizes under current systems of management of which probably none are fixed in the sense of being immutable. Every combination of crops and stock, every system of organisation and management must be fixed at a given moment and more or less over a period covering one to three years, while there are none of entirely immutable character.

In connection with organisation and general management an elaborate, illustrated, study of farm layout in relation to labour required on some farms in Wales showed (1) that the size of fields and of plots of grain and root crops varied with the size of farms; (2) the amount of manual labour used tended to vary inversely with the size of farms, while the actual labour hours per acre, which include the time given to crops, stock and "establishment" work shows a tendency to decline from the smaller to the larger farms; this decline is not proportional to the increase in size. There is greater intensity of use of land, especially by stocking, on the smaller farms, and the figures for labour expended per acre represent two items, namely, the relative disability of small farms in use of labour and the greater need of labour owing to higher intensity of stocking, and these two tendencies are pulling in opposite directions. Thus, to some extent, the disadvantage of the small farms in use of labour is overcome by heavier stocking and more intensive use of land. Still, it remains true that labour must be a relatively large item in the total costs of production of small mixed farms. Again, this deals with *what is* (or with conditions in the very recent past) and not with what *might be.* With change in equipment, combination of enterprises, general organisation, and possibly increase in size of farm, the relative advantage of the larger farms might be increased. But there is a possibility, though perhaps not quite equal, that some of the disadvantages of the small farm might also be removed by changes in equipment and combination of enterprises. Consideration of specialisation need not be restricted to large or larger scale farming. The attention of estate administrators might, perhaps, be specially directed to this and somewhat similar studies of farm layout. (Ref. 51).

The results of a study of seasonal distribution of manual and horse labour may be of special interest to farmers in Wales.

But it is of general interest to note that about 49 per cent. of all manual labour used is given to live stock, and only 33 per cent. to crops including hay, and, on the other hand, that 84 per cent. of horse-labour is used on crops, and only about 3 per cent. in direct service to live stock. As pastoral systems to some extent similar to those of Wales extend into the West of England somewhat similar conditions may be found there. In the event of movement towards higher organisation or changes in equipment, the changes must deal largely with the handling of livestock, pasture and hay. (Ref. 52).

VI.—Profitableness of Farming.

Studies in the profitableness of farming have two main objects, the discovery of amounts of incomes arising from farming operations within a given area and period; and, if possible, the exposure of causes of variations in profitableness between one farm and another, or one group of farms and others. Both purposes are usually served to some extent. If it were quite certain that the same farms were dealt with in the different years the study of production, costs, and methods of disposal of products on Yorkshire farms over eight years 1921–29 would be perhaps the most important of this type to be recorded, but in any case it deserves close attention. On the average the farms dealt with show 65 per cent. of output in the form of live stock and their products with 35 per cent. from crops; approximately the same as the estimated proportions as for the whole country. With this output the production costs consisted of 32 per cent. for labour, 24 per cent. purchased foodstuffs, 15 per cent. rent, nearly the same for upkeep of implements and tradesmen's bills, 6 per cent. fertilizers, 4 per cent. seeds, and 3 per cent. rates. Of the "social output"—the fund available for distribution between landowner, farmer and workmen—no less than 66 per cent. has been taken to meet the wage bill, 31 per cent. to pay the rent, leaving only 3 per cent. available to the farmer to meet the interest on his capital commitments and his claim for management charges. Costs are given for various crops, and the costs of horse labour are shown as varying between 7*s*. 9*d*. per day on the smallest to 4*s*. 4*d*. per day on the largest farms, but this cost does not vary quite regularly with size of farms. The most successful farms had an output of £14 per acre as compared with the average of £7 16*s*. 0*d*. Of the profit left by the stock, cows contributed three-quarters, and of "the money made by the crops," potatoes contributed nearly 43 per cent. On the average cows returned profits, but other cattle showed a loss. Breeding ewes showed a small profit; but on store sheep bought

for feeding, taken as a whole, money has been lost. In general, pigs appear to have shown only a small profit, while poultry have shown considerable profits. Indeed, it is stated that over a series of years 30 head of poultry brought in the same net return as one cow. The farmers concerned have shown adaptability to conditions by turning to production of more livestock, particularly of the types reaching maturity at a relatively early age, by increasing proportions of sale crops from the "cleaning break," by changing the methods of disposal of cereals according to market conditions, by increasing efficiency in organisation and in the use of labour, and generally by reducing unproductive expenditure (Ref. 11).

An economic survey of dairy farming in the Blackmore Vale, Wiltshire, covered for general purposes 288 farms. This is almost entirely a pastoral area: more than half the farms had no arable, the average proportion of arable was only about 9 per cent., and only about one-sixth of the farmers were selling arable crops. The bulk of the arable crops, except wheat and sugar-beet, were consumed on the farms. Over 67 per cent. of farms were described as "milk-selling," and 10 per cent. "cheesemaking." The systems of farming may be said to be specialised, for 88 per cent. of the farms included three or less enterprises. Dairy produce contributed 62 per cent. of sales and this with cattle and pigs over 90 per cent. Summer milk production predominates, the proportions in summer and winter being about 60 and 40 respectively. The bulk of the milk was sold to local factories, but some was railed to London, only about 14 per cent. was manufactured on the farms and this mainly into cheese. Variations in prices of liquid milk were numerous and considerable as has been found in other districts (Prewett, Derbyshire). This general survey is useful, but interest is concentrated in the financial results of 107 farms. Herds showed considerable variations in size, but average milk yield did not show much variation from one size group to another—from the average of 514 gallons per cow. There was practically no difference in yield between the herds on the cheesemaking farms and the average of those from which milk was sold. Over 107 farms expenses were £8 1*s.* 0*d.* per acre, and receipts £9 6*s.* 0*d.* The cheesemaking farms had expenses of £9 4*s.* 8*d.* as compared with £7 10*s.* 5*d.* on milk-selling farms, while receipts were £10 9*s.* 7*d.* and £8 12*s.* 9*d.* respectively. These expenses include estimated charges for family labour of £1 7*s.* 3*d.* per acre on milk-selling and 13*s.* 7*d.* per acre on cheesemaking farms. Total labour charges amounted to 30 per cent. of all expenses. Seven out of ten farms showed profits, but seven farms (over 6 per cent.) showed losses of over £100. Costs of producing milk on the 107 farms are shown for groups

of herds of different sizes. In groups there was not much variation from the average of a little over 9*d.* a gallon, but individual farms showed variations between about 5*d.* and 17*d.* per gallon. On 18 farms with the *highest* cost the yield was 434 gallons, with costs per cow and per gallon of £24 3*s.* 2*d.* and 13·36*d.*, while 18 farms with the *lowest* costs showed a yield of 543 gallons, and costs of £13 10*s.* 7*d.* per cow and less than 6*d.* a gallon. The average net returns from dairying were £3 9*s.* 3*d.* per cow on milk-selling and £4 6*s.* 9*d.* per cow on cheesemaking farms. Considerable variations in the net returns occurred from farm to farm, the variation being influenced more by costs of production than by the gross returns. Farms with costs of over 10*d.* were producing milk at a loss, those with costs from 8*d.* to 10*d.* had balances on the right side, and only farms with costs under 8*d.* per gallon were making substantial profits. Some causes of variations in costs on these farms are treated below, but it may be mentioned that yield appears to be one of the chief factors in costs per gallon.

The survey of the Blackmore Vale dairy farms (Ref. 12) shows that average labour costs on milk selling farms diminished as the size of herds increased, and the proportions of labour supplied by members of the farmer's family showed the same change. Depreciation is not shown here, but the figures for "surpluses on herd maintenance" are given. On 17 "purchasing" farms this "surplus" was only £2 2*s.* 8*d.*, while on 17 "rearing" farms it amounted to £4 8*s.* 1*d.* There is no exact measurement of the influence of seasonal output of milk (autumn and spring calving respectively) on costs and returns; 12 "autumn calving" herds had a yield nearly 20 per cent. higher than 12 "spring calving" herds obtained and considerably higher costs per cow with a difference between the two groups of 1*d.* in costs per gallon. The following figures illustrate the relation between output per cow and costs per gallon on 107 farms.

Yield of Milk.	Cost per gallon. Pence.
Under 400 gallons	12·90
400–500	10·11
500–600	9·15
600–700	8·18
700 gallons and over	8·57

It has not been found possible to summarise an important economic survey of Hertfordshire farms because no general average figures are provided. This may be wise policy and if the Report is read as it deserves to be by agriculturists of Hertfordshire and areas in which similar farming occurs nothing is lost

thereby. From a list of all "agricultural holdings in the county," 1,100 were chosen as a more or less random sample. These were traced, and classified according to use, and in connection with interpretation of the *Agricultural Statistics* it is important to note that only 43 per cent. were finally classified as "mixed farms" of all sizes. Those interested in general statements about agricultural holdings and their sizes should consult the full Table (Report, p. 9). From the mixed farms of all sizes 303 survey returns were obtained, and full analysis of crops, stock, capital, labour, sales, expenses and some other items is given in the text, tables, and appendices. The difficulty of dealing with the data given in this Report is further increased by the introduction of some conceptions and terms new to agricultural economics in this country. But this general statement of results can be given with some explanation of the terms.

FINANCIAL RESULTS AND OTHER ITEMS "PER FARM."

Size group (acres)	Average size (acres)	Farm Income	Remuneration for occupiers' labour	Investment Income	Interest at 5% on farm assets	Labour Income	Profit Surplus	Private drawings in kind
		£	£	£ Minus.	£	£	£ Minus.	£
1–5	2·9	9	85	76	8	+ 1	84	30
5–20	10·3	67	79	12	10	+ 57	22	30
20–50	36·6	62	100	38	26	+ 36	64	41
50–100	72·2	30	121	91	44	— 14	135	64
100–150	123·8	29	139	110	61	— 32	171	66
150–300	207·7	6	142	136	106	— 100	242	77
Over 300	425·3	137	160	23	207	— 70	230	93

Farm Income which is the difference between gross income and gross charges, is shown to be very small throughout; but gross income does not include any valuation of "drawings in kind"—house, farm produce, fuel or other material consumed by the farmer's household. *Investment income* is the farm income *minus* the amount of remuneration estimated to be due to the occupier for his own labour; as these amounts are greater than the farm income the *investment income* becomes a *minus* quantity for each group. *Labour income* is the farm income minus the amount represented by 5 per cent. on the mean value of the farm capital; so that in some groups the labour income is a *plus* and in others *minus* quantity. *Profit surplus* is the farm income minus an allowance for the occupier's own labour and for interest at 5 per cent. on the farm capital, but, strange as it may appear, this "surplus" is a missing quantity in each group case. In other words, if the use of the farm house (or its rentable value), the use of farm produce, fuel, and other materials (or their value) are not reckoned as income, if the

occupiers paid for their own labour at the rates charged, and if they paid interest at 5 per cent. on capital they would be out-of-pocket by the amounts of the " profit surplus " shown. This process of calculation obscures the fact that some profits (in the ordinary sense) were being made, but obviously earnings or real incomes of Hertfordshire farmers were very low in 1930. After analysis of the data collected it is stated that " approximately nine-tenths of the influences affecting in Hertfordshire during 1930 were covered by five factors given here in order of importance : (1) Efficiency of labour measured in terms of the gross output per £100 worth of labour ; (2) the rate of capital turnover ; (3) efficiency of livestock production measured in terms of the gross livestock output per £100 of foods ; (4) the size of the farm[1] measured in terms of gross output ; (5) the value of the dairy produce sales. One-fifth of the farms were below normal in all five factors and on these the income secured by the occupiers for their labour and management averaged *minus* £321. . . . Only one-eighth of the sample were above normal in four factors, and one-ninth in all five factors, and on these two groups the labour income averaged *plus* £463 and *plus* £499 respectively."

But there is no way of dealing adequately with this Report except by reading it with great care (Ref. 13).

A survey of 147 farms in South Oxfordshire carried out by the Agricultural Economics Research Institute gives a comparative statement of conditions in 1923 and again in 1929. This is a type of survey, new in this country, which is exceedingly interesting and useful ; for we know far too little of the nature, the direction, and degree of changes in farming. The comparison covered practically the same farms in the two years. Changes in technical systems were general. There was an increase in dairy stock ; less fattening of cattle ; increase in sale of store cattle and veal calves ; all these changes are linked with the primary change in dairy stock. In the sheep enterprise the changes were a decline in sale of fat tegs and greater sale of fat lambs ; and in pigs an increase in porkers at the expense of production of heavy baconers. On the whole, the number of stock carried appears to have declined. Although there was a decline of 16 per cent. in wheat acreage, and an increase in oats, the general distribution of arable crops showed little alteration. The decline in total arable crops was about 13 per cent. Income per acre fell from £8 17*s*. 3*d*. to £6 10*s*. 5*d*., and outgoings from £8 8*s*. 0*d*. to £6 17*s*. 7*d*. In 1923, 71 per cent. of farms showed profits, and in 1929 the same percentage showed losses. Wages rose, but numbers of workers and cost of labour

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[1] (Or) the farm business (Author).

fell during the interval. Rents were reduced, the heaviest reductions being made on the smallest and the largest farms with little change on those of from 100 to 300 acres. On the average, income exceeded outgoings by about 9*s*. per acre in 1923 and outgoings exceeded increases by about 7*s*. an acre in 1929. These sums do not represent profits and losses in the strict book-keeping sense, and they do not indicate the real incomes of the farms, but they give a fair representation of the relative position in each of the two years (Ref. 31).

The most ambitious of all studies in the profitableness of farming deals with 119 farms in Scotland. This report, as published by the Department of Agriculture for Scotland, is anonymous, but there is no secret about its authorship. Dr. J. S. King and the Advisors in Agricultural Economics in Scottish agricultural colleges have set themselves a big task in the analyses of various systems of farm management and resulting profitableness. The complexity of the data and treatment is indicated by the fact that 112 pages are required for treatment as against 28 pages for the report on 147 farms in South Oxfordshire. There is a general description of the farms as regards size, crops, stock and volume of production, with a description of their economic organisation—capital invested by owners and tenants, family and employed labour, and rate of capital turnover. Four types are dealt with, namely, cattle-feeding in the north-east; arable in the east; semi-arable sheep farms on the Border; and dairy farms in the south-west. "Average profits from trading account" for these four groups respectively were: £200, £48, £120 and £296; but in assessing incomes the estimated value of the use of the farm-house is added. Taking trading account profits plus value of house, the return on tenants' own capital was: N.E. arable, 6·5; E. arable, 1·5; Border semi-arable sheep farms, 2·4; and S.W. dairy farms, 10·2 per cent. The proportions of farms making profits were: N.E. arable, 23 out of 29; E. arable, 16 out of 27; Border semi-arable sheep, 9 out of 16; and S.W. dairy farms, 3 out of 5. The exhaustive analysis of factors underlying differences in profits cannot be summarised in the space available. No simple factors of overwhelming importance emerge, but there is a very useful discussion of total production, forms of labour supply, systems of payment and labour costs, total and classified expenditures, and the relative changes in levels of prices of crops and stock in relation to profits and losses. A discussion of the adjustments in farming suggested by the currency (1930) level of prices and costs clearly reveals the risk of trying to forecast with reference to general farm management policies in the present state of knowledge; but it is always easy to be wise after the event, and pioneers are

apt to get plenty of bruises without being kicked. Nevertheless, the suggestions of extended use of fertilisers for livestock production, and the warning against the use of cattle for making manure in the process of producing low-price crops still remain valid and probably necessary. Appended to this report is an account of farms in some Border counties, based on the general agricultural statistics, which leads the way towards making far better use of the Annual Returns made by the farmers. On the whole this report makes a definite contribution to the study of profitableness in farming in Great Britain although its value for general purposes would have been increased by considerable excision (Ref. 50).

VII.—Enterprise Studies.

Special enterprise studies may roughly be divided into two classes, one in which mainly costs and returns are treated, and one in which methods receive more consideration, but in each class there tends to be some treatment of the subject matter of the other. In some cases, also, studies of technical methods conducted without any special reference to economic conditions yield important information of an economic character. Dairying and milk production has received considerable attention as a special enterprise, and some important aspects have been dealt with in studies in the profitableness of farming (Refs. 14, 15, 16). A Welsh study of partial costs of milk production, dealing only with direct costs, shows a diminishing cost of depreciation per head as the proportion of home-bred cows in the herds increases. In herds of all home-bred cows the average depreciation was £1 11*s.* 0*d.*, and in those consisting entirely of purchased cows it was £3 9*s.* 0*d.* The "credit" for calves, otherwise the total value of calf-yield, was higher in the home-bred than the purchased herds. There was little significant difference in yield per cow between the home-bred and the purchased herds. Taking all costs of foodstuffs and pasturage, the gross and net cost fell as the yields rose in simple group classifications :—

NET COST OF FOOD PER GALLON AND YIELD OF MILK.

Group. (Yield).	Average Yield.	Net cost per gallon. Pence.
Under 550 gallons	487	5·45
550–650	596	4·79
Over 650	709	4·64
All groups	600	4·89

This study failed to reveal any significant influence of proportions of cows calving in winter and summer respectively on either yield or costs of production. And as regards labour

requirement it appears that on the current systems of herd management there is relatively little economy in the management of the larger herds. When herds exceed 15 or 20, it appears that the limit of economy in manual handling is reached unless there are innovations like the introduction of milking machines. In simple groupings the records were :—

LABOUR AND SIZE OF HERD.

No. of Cows.	Av per herd.	Hours per Cow.	Cost per cow. £ s. d.
Under 15	10	271	7 14 8
15–25	20	213	6 4 11
25 and over . . .	37	195	5 14 10
All herds	21	211	6 3 10

Wyllie has estimated that in a 35-cow herd the total annual cost of a milking machine would be about £44, or 25*s*. per cow, and after considering the general economies of the milking machine has stated that each farmer must decide for himself, in the light of his own special conditions (Ref. 26). It is now, however, becoming clear that the average normal labour requirements per cow in dairy herds ranges fairly closely round 200 hours per annum in almost any district. There are special studies of costs and returns of cheese making on farms (Ref. 14 and 53), with more general treatment in the survey of the Blackmore Vale (Ref. 12).

A special study of the cattle grazing and fattening enterprise in the Midlands showed, perhaps rather unexpectedly, that the oldest groups of bullocks made the heaviest live-weight increase, and this may be a timely reminder that biological or physiological general principles do not always operate unchecked in the sphere of economic activities. Some important findings are indicated by the following figures, but the whole Report is worthy of attention by graziers.

Age Group.	Margin between "Store" and "Fat" Price.	Expense (not inc. interest, etc.)	"Profit" (or Difference).	Live-weight Increase per week.
	£ s. d.	£ s. d.	£ s. d.	lb.
Under 2 years .	6 15 0	5 0 0	1 15 0	11.0
2–3 years . .	5 9 0	4 13 0	16 0	9·7
3 years and over .	5 12 0	4 18 0	14 0	12·0

Dividing the herds of cattle into groups as they were entirely grass fed, cake-fed throughout, or cake-fed in autumn, it was found that there was a strong tendency to loss on those cake-fed throughout, and a marked tendency to show profit under the other methods of treatment when the cattle were

bought in lean to fair condition. Cattle bought in forward and half-fat condition showed a more general tendency to yield profits but here again the losses were more frequent in the case of the cattle fed throughout the periods during which they were on the pastures. This preliminary study shows that insufficient attention has been given to the economies of the system of fattening cattle on pastures (Ref. 7).

Sheep.—Details of the structure of a cost-account for sheep are given by Wyllie (Ref. 17). Accounts for 16 farms covering 61 "farming years" between 1923 and 1929 show an average loss per farm of £91 a year equivalent to about 9½ per cent. per annum on the invested capital, without taking into account charges for management and interest. But in a comparison of results of flocks of different types on one farm it is shown that Dorset Horns made a loss and were sold off; the average profit *per lamb* sold from the "Half-Bred" (Border Leicester × Cheviot) flock was 10*s.*; from the Kent flock 9*s.*; and from the Kerry Hill flock it was only 7*s.* 1*d.*, the average number of lambs sold per 100 ewes put to the ram was 138 for Half-Breds, 129 for the Kerries, 105 for the Kents, and 111 for the Dorset Horns. Profits *per ewe* were: Half-Breds 13*s.* 9*d.*; Kerries 9*s.* 1*d.*; and Kents 9*s.* 5*d.* The most important factor in financial success under the conditions dealt with[1] is the number of lambs per 100 ewes.

Pigs.—A study of cheesemaking shows that the pigs kept, partly to consume whey, on one farm showed financial results more or less corresponding to movements in the "pig-cycle" of supplies and prices. The excess of returns over prime costs and depreciation in each of six years from 1924–25 was £58, £169, £37, £31, £134, and £130. Pig-recording is beginning to indicate some lines of economy in pork and bacon production, and the study of rationing is making the information obtained by recording all the more valuable (Ref. 18). But the most suggestive paper on pigs (Ref. 19) states *inter alia* that given the choice of the two markets it is more consistently profitable to produce pigs for bacon than for pork. In order to obtain identical profits on (*a*) small pork and (*b*) bacon *either* the price must be approximately one-third greater than that received per score of bacon pig, *or* the price per score of bacon pig must be approximately one-quarter less than that of small pork. This does not quite correspond with the opinions of farmers, even of those who make somewhat of a speciality of pig production; and if it is subsequently proved to be correct it should have a big influence on farmers' policy of production. But, it is stated, the

[1] South Eastern Agricultural College Farm, Wye.

presence of the embargo on fresh pork and when (*a*) home pig supplies are low and (*b*) bacon imports are heavy, bacon factories are unable to compete with pork prices and in these circumstances the production of small pork tends to be the more profitable enterprise. But pig producers should set before themselves the general aim of supplying the bacon market, then by using a dual purpose pig suitable for either pork or bacon they are provided with alternative outlets.

Crops.—Wyllie has paid special attention to crop costs and returns. Six years for potatoes under the conditions dealt with were not encouraging, for 660 acres on ten farms there was a total loss of £2,877 or 13*s*. 8*d*. per ton before reckoning any charges for management or interest on capital. In one case there was a profit of 15*s*. 8*d*. an acre, and in the other nine cases losses varied between £2 3*s*. 7*d*. and £8 17*s*. 9*d*. an acre. It appears that the average yield on these farms was higher than the general average yields for the South-Eastern Counties, but slightly lower than the general average yield for Kent. There is a strong suggestion that with the existing methods of cultivation the scope for reducing costs per acre is very limited. The cost of mangels was found to be 18*s*. 9*d*. a ton over 588 acres yielding about 15,000 tons. But the case for or against growing a mangel crop cannot be decided upon the cost per acre alone; its value as a foodstuff weighed against the price of some other crop or purchased cakes or meals must receive consideration. As yields show wide variation the cost must be taken against the yield, and the yield against costs of equivalent foodstuffs in other forms. Costs of growing cabbage for cattle were about £23 an acre and £1 per ton. Other root crops are also dealt with (Ref. 20).

Sugar Beet.—A very compendious report on the Sugar Beet Industry at Home and Abroad covers in some part practically all matters relating to the industry from farm operators to factory profits and creditors in the sugar market. Only a brief statement of conclusions is possible.

In England and Wales the costs of sugar beet per ton, 1924 to 1929, varied between £2 8*s*. 7*d*. with a low yield in 1927, and £1 15*s*. 0*d*. with a higher, but not the highest yield in 1929. Estimated costs in foreign countries during some recent years are given as: Belgium £1 7*s*. 0*d*., Czecho-Slovakia £1 1*s*. 9*d*., France £1 14*s*. 8*d*., Germany £1 7*s*. 5d., the Netherlands £1 3*s*. 10*d*., and U.S.A. £1 16*s*. 5*d*., with an average of these at £1 8*s*. 0*d*. per ton.

The suitability of British land and climate for beet production has been proved, even to some extent where it had not been expected. The sugar contents of beets and field and factory

by-products compares favourably with those obtained abroad. The crop is regarded as essential to intensive cultivation under some systems of farming in principal countries, and is beginning to be so regarded in Great Britain where the crop has assisted in maintaining arable cultivation. The use of by-products is tending, here as abroad, to maintain if not increase the stock-carrying capacity of farms. The industry has provided substantial employment in fields, factories, and in auxiliary industries. British labour for the industry does not compare unfavourably with foreign, but more of women's labour is used in other countries. In the factories the production season is longer than the average season abroad. The standard of technical efficiency in British factories is now approximately equal to that of foreign factories, the total cost to the State of assistance rendered to the British industry is estimated at over £29½ millions though about £2 millions of this may be presumed to have passed to the consumer in the price of sugar. The trading profits of all British factories taken together in each subsidy year varied from 6·3 of capital employed in 1925–26 to 30·5 per cent. in 1927–28. More local conditions of sugar-beet production have also been dealt with (Ref. 21).

In the wide field now covered by organised studies in agricultural economics in Great Britain there are almost of necessity some which must be passed over in a review of this character. In particular some studies which deal largely with methods of investigation have been regarded as outside the present scope; but in some other cases very useful information, with local or other special characteristics, has had to be omitted. A full list of publications is included with the References and will guide interested readers to some of these sources of information.

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THE FEEDING OF LIVE STOCK.

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The task of the reviewer of the progress of research in animal nutrition has been greatly facilitated by the issue of the new journal, *Nutrition Abstracts and Reviews*, instituted under the joint direction of the Imperial Agricultural Bureaux Council, the Medical Research Council, and the Reid Library of the Rowett Research Institute. This quarterly publication, which is available from the Reid Library at an annual subscription of 21*s*., is primarily a compilation of abstracts of all scientific and technical reports bearing upon animal nutrition, but includes in addition valuable review articles by eminent research workers dealing with the present state of knowledge of different aspects of the subject.

I.—Diet and Health.

Among these articles special interest attaches for our present purpose to the brief review by Dr. Orr (Ref. 1) of the subject of the qualitative aspects of nutrition, with special reference to farm animals. Up to the first decade of the present century it was generally assumed by physiologists that a diet was likely to meet all requirements if it provided a sufficiency of available energy (as expressed in calories) and of protein. Subsequent research, however, has demonstrated conclusively the inadequacy of this conception of the requirements of the animal, and has shown that growth, health and reproduction are dependent further upon substances which make little or no contribution to the supply of either energy or protein. Examples of this are found in the case of the vitamins and the

mineral ingredients of diets. Since most of these newly discovered factors cannot as yet be measured by the ordinary methods of chemical analysis, their study must necessarily proceed largely upon qualitative lines, so that the development of interest in these lines of work has tended to move the centre of interest in nutrition from quantity to quality. To quote Dr. Orr, "a slight difference between two diets, which can neither be detected by the eye, nor determined by chemical analysis, may yet be so important that it may mean the difference between life and death to the animals to which they are fed. Hence, in this work on the qualitative aspects of nutrition, calculations based on data of calorimetric investigations, balance experiments and chemical analysis of foodstuffs must be supplemented by clinical observations in which the adequacy or inadequacy of the diet is judged by its effects on the rate of growth and state of health of the animal. If the diet be adequate in all respects, the animals to which it is fed are maintained in health: if it be inadequate, symptoms of disease appear, and the time they take to do so and their severity tend to be in proportion to the degree of inadequacy. Studies in this modern aspect of nutrition are thus to a large extent studies of food in relation to health."

In discussing the subject of "deficiency diseases," attention is directed to the danger of applying direct to farm animals conclusions that have been arrived at through experiments on small laboratory animals such as rats. "Thus, while scurvy can be produced in guinea-pigs in three to four weeks, it is difficult, if not impossible, to produce gross signs of scurvy in either poultry or pigs; and though it is easy to produce beriberi in fowls through lack of vitamin B, cattle appear to be immune because they are able to synthesise this vitamin in the rumen. Hence the only data which have a direct bearing upon any species of farm animals are data obtained upon that species."

The danger of disease due to lack of vitamins is less in the case of farm animals than with human beings, because of the greater extent to which their dietary includes foodstuffs which are more or less in their natural state, and therefore ordinarily sufficiently well supplied with the essential vitamins to ensure that at least gross signs of deficiency disease are unlikely to appear. It is in accord with this that we find it to be mainly in the case of the most artificially reared of our farm stock—"intensively" reared chickens and young pigs reared indoors—that deficiency diseases, notably those due to lack of vitamin D, have been noted. In the case of cattle, sheep and horses such severe deficiency of vitamin as would cause actual disease seems to be rare, but it is not unlikely that in many cases the

diet may not supply the optimum amount of one or other vitamin, and that minor degrees of malnutrition, which are not uncommon, may arise from this cause.

Similar considerations arise in the case of mineral deficiencies, symptoms of disease due to which are only likely to arise in the case of animals grazing on unimproved pastures markedly deficient in one of the minerals, as, for example, in cattle grazing on the phosphorus deficient pastures of South Africa and Australia (Ref. 2), or the lime deficient pastures of our own country, or in the case of animals fed indoors for intensive production, such as pigs or poultry on rations consisting mainly of cereals and vegetable bye-products. To quote further from Orr, "the diseases which have attracted most attention are styfsiekte in cattle, rickets and osteoporosis in cattle, sheep and pigs, goitre in all the mammalian species, and primary anaemia under various names such as bush-sickness and nakuruitis in cattle and sheep. These have all been studied intensively in the last few years, and attributed to deficiency of phosphorus, calcium, iron or iodine. Some recent work seems to indicate that even in ordinary rations deficiency of chlorine gives rise to clinical symptoms, especially in poultry. With regard to other minerals, though interesting results have been obtained in the study of substances such as copper and manganese, which, like iodine, are required only in traces, there is, as yet, no sure evidence that diseases due to deficiencies of these occur in farm stock under ordinary conditions of feeding."

As yet, we know comparatively little regarding the amounts of the various essential minerals required by different animals, nor have we full knowledge of all the factors which determine what proportion of the amount of each present in the food is actually absorbed and utilised.

More widespread and of greater practical importance probably to our live-stock economy are the cases of ill-health in live stock, not sufficiently severe to be described as disease, but causing reduced efficiency of growth or production, which are traceable to faulty feeding and therefore preventable. Apart from troubles arising from infection many of the cases of decreased appetite, lowered vitality, lethargy, dull coat, slow growth, and reduced capacity for work or production are undoubtedly due to dietary deficiencies. The same may probably be said with regard to many cases of sterility and non-contagious abortion in cattle, or low hatchability of eggs and viability of chicks in the case of poultry.

Furthermore, it has always been commonly believed that the quality of the diet eaten affects susceptibility to disease, and the results of the more recent work on this point are in the

main confirmatory of this view, although not entirely concordant. Orr considers, however, that the evidence is "sufficient to warrant us in accepting as a working hypothesis the view that animals suffering from malnutrition due to an inadequate diet, may be more susceptible to some infectious disease than animals in perfect health." It is an interesting speculation as to what proportion of the heavy toll of disease on our flocks and herds is traceable to defective feeding, but to this question no answer can as yet be given.

The practical feeder must not forget, however, that just as trouble may arise from deficiencies of particular essential ingredients of the diet, so also may troubles often arise from excess. On this point the words of Dr. Orr are pregnant with practical wisdom: "It is obvious that the addition of either vitamins or minerals will produce a beneficial effect only in cases where the addition is made to a ration which is deficient in whatever is added. Indeed, any addition to a ration which already contains sufficient may be positively harmful. Too much cod liver oil added to the ration of poultry may actually decrease egg-yield, and mineral salts added unnecessarily to the feed of dairy cows may decrease milk-yield by interfering with digestion. Ergosterol, a potent source of vitamin D, given in excess may produce definite toxic results. Hence the beneficial effect noted on the addition to a ration of some vitamin or mineral should not be attributed to the vitamin or mineral *per se*, but to the fact that the addition has improved the ration. The same addition made to a different ration would have a different and possibly a harmful effect.

Even if the ration be perfect with regard to its vitamin and mineral content there still remain for consideration other qualitative aspects, such as the quantity and quality of protein, the amount and kind of fibre, palatability and digestibility. No recent addition to our knowledge has detracted from the importance of these factors." "The final objective in all our investigations is the perfectly balanced ration, that is, one in which all the essential constituents are present in the right amounts and proportions." The interest of the practical adviser in one or other aspect of dietary research must not blind him to the necessity of bringing all other factors into account in drawing up his rations. "For the successful compounding of the balanced ration, a balanced judgment is as necessary as a knowledge of the most recent results of scientific research."

Readers more specially interested in the subject of the bearing of dietary upon health and disease will find much of interest in the article in the same journal by the Dutch investigator, Sjollema (Ref. 3), which deals with various

nutritional and metabolic disorders in cattle, and in the article by the South African investigators, Theiler and Green (Ref. 2), which summarises the present state of knowledge on the subject of phosphorus deficiency in ruminants. Attention may also be directed to a further review by Orr of the general subject of faulty diet as a factor in disease in a lecture delivered at Guelph, Canada (Ref. 4). Studies of the special case of rickets in swine at the Nebraska Experiment Station (Ref. 5), have demonstrated the curative properties of sunlight and cod liver oil. In one trial sunlight alone proved fully effective, whilst in another cod liver oil used without sunlight was only completely effective in warding off rickets when the amount used was not less than 1 per cent. of the ration.

II.—Protein Supply Problems.

Just as in the general problem of nutrition as a whole qualitative factors are attracting a steadily increasing share of the interest of the research worker, so also in the special field of research into the protein needs of the animal the importance of the differences in the quality or biological value of different proteins is being increasingly realised. For the reader unversed in protein chemistry it may be explained that all proteins are complex nitrogenous bodies, produced by the "welding" together under the influence of chemical force of a variety of simpler substances, mainly belonging to the classes known as amino-acids and amides—the whole mixture of these ingredients being often referred to briefly as "amides." When the proteins of food undergo digestion they are broken up into their constituent "amides" and pass as such into the blood stream where they provide the materials out of which the proteins of the animal body and its products (milk, eggs, wool, etc.) are built up. Obviously, therefore, the value of any particular protein to the animal is likely to vary according to the amount and kind of "amides" into which it breaks up on digestion. Just as it is desirable that the ration as a whole shall be suitably "balanced" with regard to the proportion of proteins to non-protein ingredients (fats and carbohydrates) supplied by it, so also is it desirable, and to some extent essential, that the protein itself shall be nicely "balanced" as regards the kind and amount of "amides" present in it. The animal has considerable powers of adaptation to different mixtures of "amides" but for some of its purposes certain of the individual "amides" are of vital importance and their place cannot be taken by others. For example, the classical experiments of Osborne and Mendel showed that the "amide," lysine, is absolutely essential for growth in the young animal.

Proteins that do not contain lysine in their "amide" make-up cannot possibly provide fully for growth no matter how liberally they may be fed. The same applies to certain of the other "amide" ingredients, and a ration to be successful must therefore contain each of these in the make-up of its proteins and in adequate amounts. Excess of any particular "amide" beyond the specific needs of the animal is wasteful and would be avoided in a ration perfectly balanced with regard to the quality—in this sense—of its proteins. Chemical analysis of the proteins of different foods has revealed that there are great differences in their "amide" make-up; some contain all the essential "amides," though not necessarily in ideal proportions, others are defective with regard to one or more of them. Thus zein, the principal protein of maize, is lacking in the important item, tryptophane, and hence maize requires to be supplemented by some other foods whose proteins will supply the necessary tryptophane.

These considerations make it clearly important that we should have information both of the precise value of the proteins of individual foods when used alone, and when used to supplement other foods or mixtures of foods, as in the commonly used mixed ration. The work involved in getting this information is difficult and tedious, and progress therefore necessarily slow, but the matter has attracted increasing attention from biochemists in recent years and a considerable mass of information is being steadily built up. A few examples from the literature of the past year may be quoted.

Mitchell and Hamilton (Ref. 6) at the Illinois Experiment Station have studied the nutritive value for growing swine of the proteins of linseed meal and of cottonseed meal, both alone and when used to supplement the proteins of maize. The biological values (or percentage efficiency) of the three kinds of protein when used separately were practically the same, viz. 61, 63 and 61; whilst when used together no substantial improvement was shown. The practical moral, therefore, is that from the point of view of protein *quality* the addition of linseed or cottonseed foods to a maize ration does not effect any improvement.

Experiments at the Purdue Experiment Station (Ref. 7), showed on the other hand that additions of either casein or soybean definitely improved a maize ration, but that the casein was distinctly superior in this respect to the soya protein. Cooking the soybean made a marked improvement in its value. The addition of 3 per cent. of dried yeast to the diets did not effect any material improvement.

Polish workers (Ref. 8) have found that yeast proteins and soya proteins supplemented the proteins of white flour. Rye

bread proteins were superior to wheat bread proteins and were improved by admixture of soya proteins.

Closely allied with the same problem is the long-debated, and still much disputed, question of the relative efficiencies of animal and vegetable proteins. From the standpoint of the completeness and "balance" of their "amide" make-up it can hardly be doubted that the animal proteins taken individually are superior to the individual vegetable proteins, but that does not exclude the possibility of making a blend of vegetable proteins that will prove as effective in practice as the animal foods. Evidence as to the practicability of this course has been steadily accumulating in recent years. In particular the possibility of replacing fish meal by soya meal or groundnut meal, used in each case as supplements to cereal rations, has been well established (Refs. 9, 10).

Much work requires to be done before definite rules for the practical blending of foods with a view to optimum *quality* of protein can be drawn up, and meanwhile our advice to the feeder must be to provide a variety of proteins in his rations, or in other words, not to depend too much on any one class of food.

On the bearing of protein supply on growth and the processes of reproduction, interesting observations have been reported by Slonaker (Ref. 11), working at Stanford University, California. His extensive investigations made with rats have been designed to determine by observations through several generations the percentage of protein in the diet best adapted to produce maximum results in the physiological functions of the rat, in the hope of establishing certain physiological principles applicable to other animals. The earlier experiments dealt with the influence of the amount of protein supplied upon growth, five different rations being compared, each supplying the same amount of energy but varying in protein content, the percentages thereof being 10·3, 14·2, 18·2, 22·2 and 26·3 respectively. The experiment was started with 90 pairs of rats, 18 for each group. The results indicated that with the rat best growth was secured when the amount of protein in the diet was slightly in excess of 14 per cent. A deviation of 4 per cent. less or greater produced no serious difference. Outside this range, however, increase or decrease of protein caused a progressive retardation in growth.

So far as mortality was concerned, the mortality of the males in the first matings was in general greater than that of the females. For both sexes mortality was least in the 14 per cent. and 18 per cent. protein groups and highest in the 26 per cent protein group.

As to the effect on reproductive efficiency sterility was more

pronounced in the males than in the females in each group. In the 18 per cent. protein group, which had the best fertility record, the percentage fertility of the males was 87 and of the females 100, whilst for the worst group (26 per cent. protein) the corresponding values were 33 and 50 per cent. respectively.

The duration of reproductive activity for both sexes was greatest with Group II (18 per cent. protein) and lowest with Group V (26 per cent. protein), whilst the same order held for the average number of litters and the average number of young born per pair. Group II also excelled the other groups in sex ratio of the young, and percentage of the young weaned. In size of litter Group I (14 per cent.) proved rather better than Group II (18 per cent.) In general the order of efficiency in reproduction of the diets from greatest to least was 14, 10, 18, 22, and 26 per cent. protein. The average weight of young at birth, at weaning and at 280 days generally increased with increased protein in the diet. Loss of maternal weight during lactation decreased, whilst the quantity and quality of milk secretion increased, as the protein supply increased.

It would hardly be justifiable to apply these results obtained on the rat to our farm animals, but it can hardly be doubted that they point a moral as to the danger of exploiting too far the growth-promoting and milk-producing properties of proteins in the feeding of breeding stock of all kinds. Evidence of the practical importance of this in the feeding of cows for high milk-yields has been steadily accumulating in practice in recent years, and the problem is one that calls for investigation in its direct bearing upon the cow, ewe and sow.

To round off our survey of protein problems a few new papers on quantitative protein requirements may be noted.

Clausen (Ref. 12), has computed the optimum supply of protein for bacon pigs from the Danish experiments carried out by Jesperson (Ref. 88), in which pigs were fed grain foods along with skimmed milk, or blood meal plus meat and bone meal, and arrives at the following " standards."

Live Weight per head. lb.	Optimum Protein Supply per day. lb.
44– 66	0·33
132–198	0.33–about 0·66

The average for the whole growth period (66–198 lbs. live weight) was found to be 0·55–0·60 lb. digestible protein daily.

Esskuchen (Ref. 13), has studied the protein requirement of cows for the growth of the foetus, his observations being based upon the weight of the foetus at different ages in 281 cases. He found that during the first seven months of pregnancy, protein deposition in the foetus was so small that it is

negligible in feeding under practical conditions. During the last $2\frac{1}{2}$ months of pregnancy it was about 100 grammes ($3\frac{1}{2}$ ozs.) daily, so that assuming that 70 per cent. of the digestible protein of the feed is so utilised, the extra protein requirement of the mother will average about 143 grammes (5 ozs.) daily. Less than this will suffice in the eighth month, but during the last 4–6 weeks more than the average will be required, and the amount for this period may be assessed at 225 grammes (8 ozs.) per day.

On the important subject of protein and total food requirements for the production of milk a summary of the extensive Danish experiments carried out in 1922–28 has now been published (Ref. 14). These experiments comprised 600 cows that were under experiment in the first half of their lactation periods (Series A), and about 200 cows that were under experiment for the whole lactation period (Series B).

Series A was divided into three experiments. In Experiment I the amount of protein fed was varied in proportion to the milk production (calculated to weights of "standard" milk with 4 per cent. fat), whilst the total weight of food was kept constant. In Experiment II the amount of protein fed was kept constant, but the total amount of food varied, and in Experiment III both protein and total food were varied so that the cows got a different amount of food for each kilogramme[1] of "standard" milk produced, but the protein content per food unit remained the same. The cows were managed under ordinary Danish farm conditions, with a ration of roots (35–45 kg. per cow daily), meadow or alfalfa hay, oat and barley straw, and concentrates consisting of oats, barley and oil-cake.

Experiment I comprised 328 cows and the protein fed varied between 40 and 80 grammes[1] of digestible true protein per kg. of "standard" milk. A summary of the results is given in the following table in which the experimental groups are arranged in ascending order of amounts of protein fed per kg. of "standard" milk (Sm), and the percentage fall in milk yield for the first 10 weeks of the experimental period is shown.

Amount of Protein. Grms.	No. of Groups.	True Protein fed per kg. Sm. Gms.	Fall in Milk Yield %
below 45·0	8	40·3	19·2
45·0–54·9	10	50·7	16·9
55·0–64·9	12	59·4	15·4
65·0–74·9	4	69·8	19·1
Over 75·0	8	79·0	20·6

It will be noted that the milk-yield was rather better

[1] 1 Kg.=2·2 lbs.; 1 oz.=$28\frac{1}{3}$ gms.

maintained by the 12 groups receiving 55–65 gms. digestible protein per kg. Sm. than by those that received either more or less.

The second and third experiments, which comprised 267 cows, showed the following results when arranged in six equal-sized groups of 43 cows each according to the amount of "standard" milk produced per 100 production food units. (P.F.U.)[1] :—

Milk Yield in Kg. Sm. per 100 P.F.U.	Change in Live Weight of Cow. per 100 P.F.U.	Amount dig. Protein per Kg. Sm.
Kg.	Kg.	Gms.
291	—2·69	53·8
266	—0·73	55·5
244	+0·38	58·9
231	+1·00	60·1
206	+2·02	62·5
191	+1·97	67·7

It will be seen that the cows which averaged over 250 kg. Sm per 100 P.F.U. lost in weight, whilst those with average yield lower than this gained in weight.

On the basis of these three experiments it is computed that the production ration for Danish cows, if they are to maintain their live weight during the first half of the lactation period, must consist on the average of a "food unit" including about 150 gms. of digestible protein per 2·5 kgs. of "standard" milk (4 per cent. fat), which, in terms of the "starch equivalents" more commonly used in this country, means 0·27–0·28 kg. Starch Equivalent including about 60 gms. digestible protein per kg. of "standard" milk (or 2·7—2·8 lbs. Starch Equivalent, including 0·6 lb. digestible protein per gallon of 4 per cent. milk). This conclusion is in close agreement with the "standards" commonly used in milk rationing advisory work in this country.

The experiments of Series B, covering the whole lactation period, suffered from various mishaps which made the results less reliable than those of Series A, but on the whole seemed to confirm the above conclusions. Three groups of cows were fed at different levels of supply, 0·34, 0·40 and 0·46 food units being fed per kg. of "standard (4 per cent.) milk." It was found that both yield and fat content of milk increased with the level of feed intake, and that in the group fed at the highest level the effect was continued into the next lactation.

III.—Vitamins.

Vitamin research proceeds apace and produces annually a volume of literature that does not permit of more than a very

[1] One Danish Production Food Unit=1 kg. barley of good quality.

superficial survey. The first volume of *Nutrition Abstracts and Reviews* contains over 150 pages of abstracts dealing solely with vitamin investigations. Clearly, therefore, we cannot here do more than outline a few items that have attracted our attention as having an apparent interest for the agriculturist.

Attention continues to be devoted largely to the three vitamins A, D and B, which possess the greatest interest for the practical stockfeeder. The chemical nature of these factors is steadily being revealed to persistent research, and it would appear certain that vitamin A is closely associated with the yellow plant pigment, carotene, whilst vitamin D is closely related to ergosterol, and produced from it by the action of ultra-violet radiation.

Vitamin A.

Green-leaved or yellow-rooted vegetables are excellent sources of this vitamin, owing to its formation from carotene.

Moore (Ref. 15), working at Cambridge, has demonstrated the power of the cow to convert carotene into Vitamin A. Both are present in milk-fat, and the amount of each is increased by feeding carrots to cows at the end of the winter stall-feeding period. Jersey cows pass more unchanged carotene into the milk-fat than do Shorthorns, under similar nutritive conditions. During pasture feeding the supplies of carotene and vitamin A in the food are far in excess of the amounts removed in the milk, but during stall-feeding the drain on the reserves of the cow's body may be serious. This may be avoided by including in the ration a small allowance of carrots or other substance rich in carotene.

Experiments at Belfast (Ref. 16), with poultry have demonstrated similarly that chickens also have the power of producing Vitamin A from carotene, and that their requirements for this factor are relatively large. It seems probable therefore, that this power is common to all classes of farm animals, although their relative needs for Vitamin A may vary considerably.

In view of the common occurrence of vitamins in greenstuffs, and the extent to which these are dried before use, it is of obvious interest to know what is likely to be the effect of the drying process upon the vitamin-content of the product. On this point, so far as it concerns Vitamin A, some information is available from experiments with lucerne at the Indiana Experiment Station (Ref. 17). It was found that when dried in the field the lucerne suffered greater loss of Vitamin A, than when artificially dried by hot air or hot "flue gas." Neither the high temperature used in artificial drying nor the ultra-violet rays of the sun were destructive to the vitamin,

but the evidence pointed rather to enzymes as the destructive agents. Warmth and moisture favoured the destruction of the vitamin, whilst cold, rapid drying, or heating under pressure, hindered it.

Vitamin B.

This vitamin is now known to be a complex of two or more vitamins (Ref. 18), the best known of which are designated provisionally as B^1 and B^2. The volume of work relating to it is growing rapidly, and there is increasing evidence of its practical importance for livestock that are kept under highly artificial conditions, such as chickens in "battery" brooders. We can only refer briefly to a few papers on the distribution of the B vitamins in various foods.

Roscoe (Ref. 19) found that carrots contained one-fifth, turnips rather less than one-fifth, and potatoes one-fifteenth, as much vitamins B^1 and B^2 as yeast, all these sources, including yeast, being twice as potent in B^1 as in B^2. New carrots were no better than stored ones, nor did steaming carrots render the contained vitamins more available.

Day (Ref. 20), in America, found that beets, carrots, potatoes and turnips contained small and approximately equal amounts of B^2. The leaves of beet, carrot and turnip were found to be good sources of this vitamin, containing from 4 to 6 times as much as the corresponding roots.

Scheunert (Ref. 21) reports that moderate amounts of the vitamin B complex were found in most of the common vegetables, and that very little of it was destroyed by boiling.

In experiments at the Illinois Experiment Station (Ref. 22), 25 per cent. of oats, maize or wheat in an experimental diet provided sufficient vitamin B^1 for the normal growth of rats, but double the amount was required to satisfy the need for Vitamin B^2. The oat kernal contained more of the Vitamin B complex than the endosperm. For lactation 50 per cent. of oats was needed to provide Vitamin B^1, but three to four times as much was required for Vitamin B^2.

Vitamin D.

Our knowledge of the nature and functions of this vitamin is probably more complete than that of any other, and has now been rounded off by the isolation of the vitamin in a practically pure state. In a lecture before the British Science Guild, reported in *The Times* of 25th October, 1931, Dr. Dale, the Director of the National Institute for Medical Research, exhibited a small quantity of material prepared by some of his colleagues, and dubbed "calciferol," which, in his words, "seems to be the pure rickets-healing vitamin. This little

pinch of white crystals (about 1/300 oz.) would suffice to cure a severe degree of rickets in some 400,000 young rats. In its power of preventing or curing rickets, one gramme of this substance would be equivalent to about half a ton of cod liver oil, though cod liver oil contains another vitamin (A), at least as important as this."

That Vitamin D is associated with the assimilation of calcium (lime) is now familiar knowledge, but its mode of action remains obscure, although recent work by Harris at Cambridge makes it probable that the vitamin acts by maintaining the concentration of calcium and phosphorus in the blood at a constant and optional level. As long as these minerals are available at the proper degree of concentration calcification of bones can proceed. Vitamin D produces this effect by controlling the amount of the mineral absorbed from the food through the wall of the bowel. If excess of Vitamin D is taken into the body excess absorption of mineral matters occurs, the level of calcium in the blood rises and densely calcified new bone is formed.

This vitamin is the one that probably is deficient under farm conditions more frequently than any other, but the conditions that may give rise to deficiency of Vitamin D, and the measures by which it can be counteracted, such as the feeding of greenstuffs, cod liver oil or milk, or exposure to sunlight or ultra-violet radiation are now fairly well understood.

IV.—Irradiation.

The discovery of the production of Vitamin D through the action of ultra-violet radiation on ergosterol, has now been supplemented by the production of Vitamin A in similar fashion by irradiation of carotene. The rays which produce Vitamin A fall, however, in a different part of the ultra-violet region of the spectrum from that which is effective in producing Vitamin D. For each of the two vitamins there is a restricted range of wavelengths within which irradiation is effective, and outside this are radiations that may be destructive rather than productive of the vitamins. Much still remains to be learnt as to the technique of irradiation, and it is perhaps not surprising that, apart from its application to the cure of rickets, the attempts to enhance the efficiency of production under practical farm conditions by irradiation of animals have mostly proved disappointing (Refs. 23, 24). Better success has attended the efforts to increase the vitamin potency of milk by feeding irradiated yeast or ergosterol to the cow (Refs. 25, 26), or by direct irradiation of milk (Ref. 25a).

V.—Mineral Supply Problems.

The major problems of mineral supply relate to the elements calcium and phosphorus, owing to the large amounts of these elements that enter into the composition of the skeleton. A considerable literature has grown up, however, round the elements, such as iron, iodine, manganese, etc., which are present in the animal in only very small proportions, but which conceivably may play important parts in metabolism. A summary by Godden (Ref. 26a), of existing knowledge as to the significance of the elements iodine, iron, copper, manganese and aluminium in animal nutrition leads to the conclusion that the three last-named elements are unlikely to be deficient in any ordinary mixed ration used on the farm. A few reports of interest dealing with other elements may be noted.

Experiments at Aberdeen (Ref. 27) with growing sheep kept both indoors and outdoors on a calcium-deficient ration showed markedly better growth under outdoor conditions. The difference appeared to be due to deficiency of Vitamin D, and disappeared when cod liver oil was added to the ration of the indoor sheep, whereas addition of lime had no effect on growth. The actual cause of the improvement effected by the Vitamin D supplied by the cod liver oil appeared to be an improved utilisation of the phosphorus, rather than of the calcium, of the diet—an interesting illustration of the close interdependence of these two elements in animal metabolism. An adequate supply of lime in the ration is not sufficient in itself, but in addition a further factor is necessary to ensure efficient utilisation. From the results of the Aberdeen experiments it would appear that this factor is supplied by cod liver oil and by summer sunlight, but not sufficiently by winter sunlight.

In American experiments (Ref. 28) the relative merits of various materials as sources of calcium for growing swine were compared. The substances tested were limestone, sulphate of lime and bone meal, and all proved of practically equal value.

Information as to the actual requirements of individual mineral elements by the various classes of live stock under different conditions still remains scanty and leaves the adjustment of the mineral "balance" of rations very much a matter of guesswork. In a review of the calcium and phosphorus requirements of the milch cow, Linton (Ref. 29) concludes that the Kellner standards, as set out below, are probably adequate, at least for moderately heavy milkers.

	Calcium. Gms.	Phosphorus. Gms.
Maintenance, plus 1 gallon	41·2	17
,, ,, 2 gallons	49·9	24
,, ,, 3 ,, ...	58·6	31
,, ,, 4 ,, ...	67·3	38
,, ,, 5 ,, ...	76·0	45

Standard rations including a fair proportion (say 14 lbs.) of good quality hay will probably cover these requirements up to 4 gallons, without any special mineral supplement, provided sufficient Vitamin D is also present, but if the hay be poor and vitamin deficient, the use of a mineral supplement will probably be necessary at a much lower level of production if loss of lime and phosphorus from the reserves in the cow's body is to be reduced to a minimum.

Information on the mineral requirements of pregnant sows is now available from experiments at Cambridge (Ref. 30). From the results it is concluded that the only supplements necessary are lime and salt, and that for the in-pig sow that has not access to good grazing a mixture of 4 parts of ground chalk with one part of common salt should be fed at the rate of 1 oz. per head daily. During lactation the allowance will need to be raised to about 2½ ozs. of the mixture per head daily. These conclusions apply only where the ration does not include ingredients (*e.g.* fish meal) that are relatively rich in lime and salt.

The deficiency of cereal meals in salt for the needs of growing and fattening pigs was also clearly demonstrated in the Harper Adams experiments (Ref. 31), which showed on the other hand that no special supplement of phosphorus was necessary.

The importance of common salt in the feeding of farm animals has been a matter of general knowledge from the earliest times, but precise data as to actual salt requirements are distinctly meagre. In a brief review of the subject Thomson (Ref. 32), quoting from the older experimental work, puts the probable daily requirements (in ounces) at 0·71–1·5 for the cow, 0·5–1·0 for the horse, and 0·12–0·25 for sheep and pigs. Modern developments towards earlier maturity and higher milk yields make it probable, however, that these old "standards" are now too low, and this was confirmed by observations on the individual salt-consumption of each of 17 Ayrshire cows. All the cows were fed the same ration and were not out at grass during the two years over which the observations were made. Salt was added to the maintenance ration at the rate of 0·7 oz. per cow daily, and to the production ration at the rate of 0·6 oz. per gallon of milk, whilst in addition every cow had access to a pure salt "lick."

The differences in salt consumption throughout the herd were very great and could not be correlated with the milk yield nor with the length of the interval between calvings. Of special interest, however, was the observation that the cows invariably licked most vigorously during the few weeks before and after calving. With few exceptions fully one-half of the annual

consumption of salt occurred during the 18 weeks round about the date of calving.

The cows yielding 5 gallons of milk daily consumed on the average about 7 ozs. salt daily in their food and from the "lick," a figure far in excess of the old "standard" quoted above. It is estimated that 130 lb. of good pasture grass would be required to supply this amount of salt, so that the current view that animals on good pasture do not require any mineral supplement, including salt, may require modification in cases of high milk yields.

The possibilities of deficiency of iron in the food of young animals have received a good deal of attention in recent years, and, particularly in the case of suckling pigs, it is now clear that many cases of trouble arising in practice are due to this cause, especially the check to growth that so commonly occurs when the pigs are three to four weeks old, and which in severe cases is associated with "scour." Administration of small doses of ferric sulphate, especially if accompanied by a minute amount of copper sulphate, is found to be effective in preventing or curing the trouble.

The evidence on the subject of the importance of iodine in farm feeding still remains conflicting. A comprehensive summary of recent experimental work on the subject has been published by Scharrer (Ref. 33), but without any attempt at critical examination of the validity of the individual experiments. Taking the data as they stand the balance of evidence indicates that under certain conditions, which cannot as yet be defined, additions of iodine to the rations of breeding stock may have a favourable influence upon fertility and upon milk secretion. The evidence as to any effect upon growth of continuing the iodine feeding after weaning is more ambiguous.

Information as to the iodine-content of feeding-stuffs is very scanty and the following data from a Norwegian source (Ref. 34), may be of interest.

No. of Samples.	Foodstuff.	Iodine Content in Milligrams per Kg. Range.	Average.
6	Herring Meal	1·27–3·44	2·23
4	Liver Meal	3·77–5·77	4·86
2	Meat ,, ...	0·00–0·64	—
2	Linseed Cake	0·48–0·49	0·49
3	Coconut ,, ...	0·33–1·15	0·62
6	Soya ,, ...	0·66–3·03	1·97
5	Earthnut Meal	0·00–3·20	—
3	Tapioca Flour	0·00–0·82	—
3	Beet Molasses	1·56–3·01	2·21
5	Milling Offals	0·06–0·86	0·53
1	Maize Meal	0·74	—
1	Lucerne Meal	0·00	—
5	Green Fodder	0·00–0·82	—
12	Hay	0·00–0·99	—

The chief interest in these figures is in the great degree of variability shown as between different feeding stuffs and between different samples of the same feeding stuff.

VI.—Fibre.

The question of the significance and nutritive value of the so-called " fibre " of food has long been a matter of controversy and continues to arouse considerable interest. The item returned under this heading in the analysis of a foodstuff or ration represents the organic matter that resists solution by dilute acid and alkali when treated under conditions that have been standardised. It is thus essentially a conventional figure, and the " fibre " does not represent a definite chemical entity, but may vary considerably in its chemical " make-up " according to the material tested. When the method of estimation was first devised it was thought that the " fibre " would give a rough measure of the indigestible part of the food, but this idea has long been abandoned, and it is now familiar knowledge that the " fibre " is capable of being digested to some extent by most classes of animals, and often to a considerable extent by ruminants. The digestible portion of the " fibre " would appear to be cellulose, this being broken down in the digestive tract, not by enzymes but by bacteria or other micro-organisms. Under ideal conditions pure digested cellulose can produce as high nutritive effects as starch, but when intermingled with highly lignified ingredients, as in mature plant tissues, the digestibility and nutritive effect may be much lower, or in other words the physical nature of the " fibre " may do more to determine its nutritive value than its actual chemical composition. This is clearly brought out in the interesting experiments of Woodman and Stewart (Ref. 35) at Cambridge in which the action of cellulose-dissolving bacteria on various foodstuffs has been studied. These experiments have also given indications that the presence of oil in foods may tend to cause some lowering of the apparent digestibility of the " fibre."

The variability of the digestibility of " fibre " in the same food according to its physical condition is also brought out in German experiments (Ref. 36) on the digestibility of the " fibre " of different cereals by poultry and waterfowl. In these tests no relation was found between the digestibility and the amount of " fibre " present in the grain, but the quantity of the food consumed had a direct effect on the digestibility coefficient, the latter tending to fall with increasing consumption. Pigeons showed a higher, and waterfowl a lower power of digesting cereal " fibre " than the hen.

Closely associated with the question of " fibre " is that of

" bulk " in rations, which has aroused considerable interest in practical circles in recent years. The importance of paying some regard to " bulk " in the use of roughages, such as hay and straw, requires no argument, but the further claim that the bulk factor may also require special attention in the case of the concentrated foods is perhaps more debateable and certainly does not rest upon experimental investigation. Recent experiments at the Michigan Experiment Station (Ref. 37), suggest on the contrary that with dairy cattle at any rate the question of bulk in the concentrate ration is of little practical consequence.

VII.—Influence of Food Fat upon Quality of Body Fat and Butter Fat.

The question of the nature and extent of the influences that the food of an animal, and particularly the oil present in it, may exercise upon the quality, flavour and palatability of the meat fat or milk fat produced by it has long been the subject of investigation, but apart from a few broad generalisations little in the way of definite guidance has yet been secured for the practical feeder. The increased importance that is now being attached to the quality factor in human dietary has stimulated renewed interest in the subject on the part of investigators in recent years.

It would seem probable that the oil present in a food would be the most potent of its ingredients in its effects upon the quality of the animal fats, and that it does exercise a more or less direct effect of this kind has been clearly demonstrated. Those interested in the chemical problems involved will find much of interest in the work at Liverpool of Hilditch and his colleagues, which appears in recent volumes of the *Biochemical Journal* (Refs. 38, 39).

Their examination of the body fats of pigs indicates that a discrimination should be made between the outer and inner layers of the back fat and the internal or " leaf " fat. The food fat was found to have a marked influence on the character of the " leaf " and inner back fats, the outer layer of back fat being much less affected by variations of diet. This relative constancy of the outer back fat in composition may perhaps be determined by adjustment of the nature of the fat nearest the skin to a more or less constant consistency adapted to the average temperature conditions of the atmosphere. If this be so, warm conditions should tend to harden, and cold conditions to soften this layer of fat.

Although the food fat may produce these effects the evidence is clear that a large proportion of the normal fat of the pig is

produced from carbohydrates or other non-fatty part of the feed, so that the influence of variations in the nature and amount of the oil in it may be relatively small. This appeared to be the case in experiments devised to test the effect of degerming maize upon the quality of bacon (Ref. 40).

The question of the influence of food on the consistency and palatability of butter fat has a special interest for the Scandinavian countries with their extensive butter-making industries, and the matter has consequently been frequently the subject of investigation in these countries, especially in Denmark. For much of the older work we are also indebted to American investigators. A review of the whole subject together with new Danish experiments is now available (Ref. 41) and some of the conclusions may be quoted here.

The consistency of butter is influenced by the individuality of the cow, the nature of the food, and the mode of manufacture of the butter. So far as the influence of food is concerned, grass pastures and other green feeds give a soft butter, especially where red clover predominates in the pasture. Hay and silage from such material do not produce this effect to anything like the same extent, but silage is rather more effective in softening the butter than hay. Roughages and roots in general give a hard and firm butter. There is little difference between hay and straw. Cereals give good consistency, especially oats, though barley tends to give a rather hard butter. Peas and other leguminous grains give a butter of very hard and crumbly texture. The effect of oil-cakes and meals varies with the amount and "iodine value" of the oils they contain. Oils which have a higher "iodine value" than the average of that which is desirable in butter-fat tend to soften the butter, whilst those whose "iodine value" is below this average tend to give a hard butter, as do the extracted oilseed meals poor in oil. The ordinary concentrated foods used for dairy cows are classified as follows, with regard to their effect on the consistency of butter :—

A. *Foods which give a winter butter of normal consistency.*
Groundnut, cottonseed, and soya cakes ; sunflower seed meal ; oats, mixed cereals, wheat bran.

B. *Foods which give a markedly soft butter.*
Sunflower seed cake, rape cake, sesame cake, linseed cake, soya beans, dried brewers' grains.

C. *Foods that give hard butter.*
Coconut cake, palm kernel cake, babassu cake, extracted oil meals, pea and other leguminous meals.

The effect of a change of feed on the butter is usually

evident within eight days with foods of classes B or C, but the effect may vary in intensity as between individual cows. These variations seem to be in part matters of "individuality," but in part also are dependent upon the stage of lactation. Feeds may be so combined that the consistency of the butter is altered as desired. The excessively soft butter produced in summer through grazing pasture that is too clovery may be improved by moving the cows periodically to a more grassy field and giving a supplement of coarser greenstuff, roots, straw, or small amounts of concentrates of the C class.

VIII.—Digestion.

The subject of the digestion of foods is of perennial interest and importance, and a few of the recent contributions of agricultural interest may be briefly reviewed here.

From the Cambridge Nutrition Research Institute, further reports have been issued by Woodman and his colleagues dealing with the digestibility and nutritive value for pigs of oats in various forms (Ref. 42) and of degermed maize (Ref. 43). Considerable differences were found in the digestibility of the organic matter of oats according to the degree of fineness of grinding, the percentage digestibility found being 56·7 per cent. in the case of "crushed oats," 67·5 per cent. for "farm ground oats" and 75·9 per cent. for "Sussex ground oats." On the basis of these data it is computed that for pigs 1·1 lb. of "Sussex ground oats," or 1·2 lb. of "farm ground oats," or 1·45 lb. of crushed oats would be required to replace 1 lb. of barley meal. Practical feeding experiments reported in the same paper that will be noted later put a rather higher value on the "farm ground oats."

In the trials with degermed maize meal, which had been subjected to a steam-cooking process and dried, the results showed it to be equal in respect of digestibility to ordinary flaked maize, and significantly superior to raw maize meal and barley meal. It is estimated from the digestibility data that 1 lb. of degermed maize as used in these tests could replace 1·1 lb. of ordinary maize meal or 1·2 lb. of barley meal in the rations of growing pigs. There is the further advantage that the absence of the maize germ gives an improvement in the quality of the bacon fat (Ref. 40), and thereby makes it possible to use maize more freely in pig fattening.

A useful contribution to the data available on the digestibility and nutritive value of pasture grass and hay under different conditions is contained in a recent report from the Research Laboratory of the Royal Agricultural College, Copenhagen (Ref. 44). Digestibility tests on two cows with

hay—(*a*) first crop, cut early; (*b*) first crop cut later, and (*c*) second crop—gave percentage digestibilities as follows :—

Hay.	Organic Matter.	Ash.	Crude Protein.	True Protein.	"Oil."	Fibre	Sol. "Carbohydrates."
a	64	37	57	54	63	68	68
b	66	44	55	52	57	59	73
c	62	44	60	58	41	60	65

In other experiments it was shown that hay from young grass had a higher feeding value than hay cut at the usual time, and that silage from a clover-grass meadow cut three times during the summer was of the same value for milk production as hay from the same field. The loss of dry matter from cutting to feeding was about 20 per cent. in each case.

In view of the comparative paucity of data on the digestibility of roots some recent Continental determinations of the digestibility of mangolds by sheep and cattle may be noted. In German experiments (Ref. 45) with sheep four samples of two varieties were tested and gave the following average percentage digestibilities :—Organic matter 93, crude protein 76·5, carbohydrates 96, fibre 84. The amount of oil in mangolds is so small that its digestibility cannot be measured. On the basis of the results the production starch equivalent of the mangolds was assessed at 8·5 per cent. (equivalent to 59·3 per cent. for the dry matter), the range of variation in the four samples being 6·8–9·7 for the roots as fed, or 58·5–59·9 per cent. for the dry matter. The protein figures are of special interest, the average crude protein in the roots being 1·35 per cent., of which 0·76 per cent., or little more than one-half, was true protein. From these figures and the digestibility data it follows that the roots as consumed contained on the average 0·43 per cent. of digestibile true protein (or 0·73 per cent. "protein equivalent"). In the tables issued by the Ministry of Agriculture (Bulletin No. 48) the percentage of digestibile true protein in mangolds is given as 0·1 per cent. (corresponding to 0·4 per cent. "protein equivalent") and since there is further warrant from Continental work for the higher figure given above it is clearly desirable that the matter should be investigated with reference to the types and varieties of mangolds grown in this country. A content of 0·4 per cent. digestible protein is still small, but in view of the large quantities of mangolds commonly included in rations the difference between 0·4 and 0·1 (or between 0·7 and 0·4 in the case of "protein equivalent") cannot be ignored in our calculations of the amounts of protein suppled to live stock.

The digestibility of two varieties of mangolds by cattle has been determined at the Budapest Experiment Station (Ref. 46). The two varieties differed widely in character, the

one containing 14·5 per cent. of dry matter and the other, 22·1 per cent., the latter being obviously essentially a sugar beet rather than a mangold. This is further evidenced by the fact that its dry matter contained 61·6 per cent. of sugar, as compared with 51·5 per cent. for the other variety. The digestibility of the organic matter was found to be 91 per cent. for the "low sugar" and 83 per cent. for the "high sugar" variety, figures that agree well with the German results quoted above. Owing to the rather wide nutritive ratios of the rations used the data for protein digestibility proved unreliable, but a large number of tests made by the method of artificial digestion gave an average digestibility of 76 per cent. for the crude protein and 64 per cent. for the true protein—again in close agreement with the German results, as was also the estimated production starch equivalent of 59·0 per cent. for the dry matter. The Hungarian report contains further matter of interest based upon the analysis of sixty samples from six different types of mangolds. On the basis of the sugar content of the dry matter a classification of mangolds is given into three groups containing 35, 45, and 50 (or more) per cent. of sugar respectively in the dry matter. The proportion of true protein in the crude protein of the roots varied between wide limits, with an average of 62 per cent. for ten varieties. The average crude protein content of the Hungarian mangolds was 1·12 per cent., with true protein 0·74 per cent., and digestible true protein 0·47 per cent. (or digestible protein equivalent, 0·66 per cent). These data give further support to the suggestion made above for a revision of the data for the digestible protein of roots as commonly used in rationing advisory work in this country.

In previous Reports emphasis has been placed upon the need for more information as to the *rate* of digestion and reference may therefore be made to results obtained with pigs in recent work at the Institute of Animal Physiology in Berlin (Ref. 47). By collecting the faeces in 12-hour periods it was found that excretion of undigested material began after 13 to 15 hours when barley meal was fed in the evening, and after 11 to 13 hours when fed in the morning. After evening feeding the maximum rate of excretion—varying from 49 to 62 per cent. of the total excretion—occurred in the third 12-hour period; after morning feeding the maximum, 54 to 63 per cent., occurred in the second 12-hour period. Excretion was complete in 4 to 5 days. This difference is attributed to the fact that the quantity of faeces during the twelve daytime hours is always greater than during the night hours, because the rectum and colon can contain a larger quantity of faeces during rest, on account of diminished tone, and so evacuation takes

place less frequently. The bulk and kind of food used showed no consistent effect upon the course of excretion, but if a low supply of food were continued for a length of time the completion of excretion was delayed.

IX.—Maintenance Requirements and Feeding Standards.

The bases upon which the modern scientific methods of assessing the food energy requirements of animals rest are receiving considerable attention, especially at the hands of American investigators. It is customary, where possible, to assess the requirements for maintenance and for production separately, and to assume that the former will vary for different animals of the same class in proportion to the area of body surface exposed (or roughly in proportion to the square of the cube root of the live-weight), and that the production requirement will be directly proportional to the amount of production. The research of recent years makes it probable, however, that these simple assumptions are only valid within rather narrow limits, outside which the assessment of food requirements becomes more complicated.

That the "surface law" of maintenance requirements does not hold good for the young, growing animal was demonstrated in the earlier calorimetric work at Cambridge, and there can be little doubt now that even with adult animals disturbing factors need to be taken into account. Even the theoretical basis of the doctrine that basal metabolism is related exactly to surface area is called in question by Kleiber (Ref. 48) after a critical examination of the various theories adduced in support of the surface law, and he expresses the opinion that a more accurate relationship in terms of body weight can probably be found.

Hendricks and Titus (Ref. 49) in discussing published work on the maintenance requirement of the adult sheep call in question the validity of the surface law where differences in live-weight are small, as the effect of small differences in surface area may be obscured by effects of other factors contributing to the maintenance requirement. It is possible under such conditions for the effect of these factors to be such as to cause a higher maintenance requirement for the lighter than for the heavier animal. They believe that the maintenance requirement is affected to some extent by the level of food intake as well as by the size and activity of the animal. They also point out that surface area is not always proportional to the two-thirds power (square of cube root) of the live-weight, so that this may be an unreliable basis of comparison to use. If, for example, the animals are not uniform with regard to "con-

dition," a heavy animal will not necessarily have a correspondingly greater surface area than a somewhat lighter animal. "Condition" also, in their opinion, is a determinative factor in connection with the relation of amount of feed to gains or losses in live-weight, since it is the chemical composition of the material produced or used up in these gains or losses that chiefly determines the amount of feed to which they are equivalent, and this chemical composition is dependent, at least in part, upon the "condition" of the animal.

On the side of "production" the foundations of our simple rationing procedure are undermined by the experiments at the Pennsylvania Institute of Animal Nutrition (Ref. 50) with maize meal and lucerne hay fed separately and together. We are wont to assume that the "nett energy" (production value or "starch equivalent") of a mixture of foods is equal to the sum of the nett energies of the component items, but such did not prove to be the case in these experiments. On the contrary, the nett energy value (or value for production purposes) of the maize was much greater when fed with the hay than when fed alone. These results indicate that the nett energy value of a feeding stuff may differ according to the proportion in which it is incorporated in the ration. In the view of these American workers consistent nett energy values can only be obtained when the diet contains proteins, minerals and vitamins in optimum proportions.

In other experiments at the same centre (Ref. 51) the subject of the relation of the amount of food to the energy changes in cattle has been further studied. In these experiments the amount of heat produced by the animal, which is a measure of the energy changes, was determined at different levels of nutrition ranging from fasting to a food supply equal to three times the maintenance requirements of energy. Apart from the measurement of the total heat production it was possible to ascertain how much of it came from the utilisation of protein, carbohydrate and fat respectively, as well as from the production of fat from carbohydrate in the body.

With the heat production under fasting conditions as the base value, the heat production increased slowly as the food supply was increased up to maintenance, and much more rapidly above maintenance, but then more slowly after the level of one-and-a-half to twice maintenance was reached. The proportion of the total heat production derived from the breakdown of protein in the body varied but little at the different levels of nutrition, being about 15 per cent. Under fasting conditions the heat production was derived mainly from fat, this contributing about 85 per cent. of the total. As the food supply increased the burning up of fat steadily

decreased, until at maintenance level it ceased altogether. The contribution of carbohydrate to the heat total is complementary to that of fat, being zero under fasting conditions, and increasing to a maximum at maintenance level. Above maintenance the proportion of the heat production derived from carbohydrate varies but little, but a small amount of heat arises from the manufacture of fat from carbohydrate in the body. In these experiments also the nett energy of the rations proved to be variable, a different value being obtained at each level of feeding.

Other studies of similar character relating to growing calves, pigs and lambs have also been carried out at the Missouri Experiment Station (Ref. 52).

Turning to the more practical aspects of the determination of food values and requirements note may first be taken of a further contribution by Fingerling (Ref. 53) from the Leipzig-Möckern Experiment Station where the classic researches of Kellner were carried out. In previous experiments (1914) with a single pig Fingerling obtained results that suggested that the pure proteins, oils and carbohydrates were 30 to 35 per cent. more efficient for the production of fattening increase in the pig than in the ruminant. The later experiments, now published, which were carried out with two adult pigs and one young pig, have fully confirmed this conclusion, the average amount of fat produced by the pigs from unit weight of starch being in this case 30·8 per cent. higher than Kellner's average for ruminants. No difference was found in the productive efficiency of the starch as between adult and young animals. These results probably do not affect the validity of the application of the ordinary Kellner "starch equivalents" to the rationing of pigs, so long as we are only concerned with the comparison of rations, except possibly where the rations compared differ considerably in fibre-content and ease of digestion.

Experiments on sheep-feeding at the University of Halle (Refs. 54, 55) have led to the following feeding standards :—

Class.	Age or Weight.	Daily Feed Requirements, Gms.	
		Dig. Protein. Gms.	Starch Equiv. Gms.
Ewes (Maintenance)	50–60 kg.	50–60	415–500
„ (Lactation, 1 lamb)	„	115	750
„ („ 2 lambs)	„	155	900
Lambs	4 weeks	10	75
„	8 „	35	200
„	12 „	90	400
„	16 „	160	650
Fattening Sheep	Adult	80–100	700–800

From the same source (Ref. 56) come also new standards for fattening young cattle, as follows :—

Live Weight. Kg.	Digestible Protein. Kg.	Starch Equivalent. Kg.
150	0·4	1·4
200	0·5 –0·55	2·0
250	0·7 –0·75	3·4
300	0·75–0·85	3·8
400–500	0·9 –1·00	4·4–4·8

These figures are well below the standards commonly used in this country and certainly would not be adequate for "baby beef" production.

In last year's Report (p. 130) feeding standards for heavy working horses were given based upon investigations made at Breslau. These have now (Ref. 57) been slightly modified and amplified into the following table of requirements per 1,000 lb. live weight per day :—

	Dry Matter. Lb.	Dig. Protein. Lb.	Starch Equiv. Lb.
Rest	13·7	0·61	5·2
Light Work	16·3	0·75	6·6
Medium Work	21·5	1·04	8·7
Hard Work	27·4	1·82	12·7
Very Hard Work	28·5	1·85	14·8

It is calculated that lactating mares will require a ration with 16·5 lbs. starch equivalent, including 1·9 lb. digestible protein, per 1,000 lb. live-weight.

X.—Pasture Research.

Interest in the study of the composition and nutritive value of pasture herbage continues to grow, and reports are now appearing annually from many different countries. The basic observations that the yield and nutritive value of pasture are enhanced by systematic grazing combined with nitrogenous manuring have now been widely confirmed and the attention of investigators is being turned more to the elucidation of detail and the study of the influence of various factors. In particular the precise effect of nitrogenous manuring on the composition of the herbage is attracting considerable attention.

In continuation of the Cambridge investigations, Woodman (Ref. 58) has studied this point on the herbage of the droughty season of 1929 and the wet season of 1930. The plots receiving sulphate of ammonia gave herbage slightly richer in protein, but poorer in lime than those that did not receive the nitrogenous dressing. This effect on the lime content was more marked in the second season owing to reduction of the proportion of clover in the herbage. No effect of the nitrogenous

manuring was to be observed on the phosphorus content, but there were indications that it may have helped the grass to maintain a higher potash content during dry spells.

A report from the Hertfordshire Farm Institute (Ref. 59) on a three years' trial of the now familiar "New System of Grassland Management" on a good pasture, confirms the effect of added nitrogen in raising the protein content of the herbage, the difference being about 2½ per cent. on the dry matter, as compared with the "no nitrogen" plots. In the spring grass about 4 weeks old contained about 20 per cent. of crude protein, whilst in the early summer grass, about 5 weeks old, the proportion fell to 14·5 per cent. In a wet season the protein content was found to rise to 20 per cent. or more in the late summer. The application of nitrogen tended to suppress the clovers, Meadow Grasses and Yorkshire Fog, to increase Sheep's Fescue, and to maintain or increase the proportion of rye grasses. The rotational grazing without nitrogen tended to encourage "weeds," but the use of nitrogenous manure counteracted this to some extent. The total grazing improvement effected by the nitrogenous manurings (3 cwts per acre, per annum) was computed at between 20 and 30 per cent., but might have been greater but for the improvement effected in the pasture prior to the experiment.

A further and more detailed investigation of the same subject has been made by the research staff of Imperial Chemical Industries (Ref. 60) with the herbage grown on special experimental plots at Jealott's Hill in 1929 and 1930. As elsewhere it was found that the magnitude of the effects was governed by climatic conditions. In a favourable year for growth (1930) the increase in dry matter over the grazing season due to the application of nitrogen was about 60 per cent. on a heavy yield. Grazing was available 13 days earlier on the fertilized area and about 12 per cent. of the total increase of dry matter was obtained during this period. The mid-season yield was higher, and 15 days more grazing were produced in August and September by the use of nitrogen. In the dry year, 1929, the total increase produced by the nitrogenous manuring was 41·5 per cent., on a much lighter crop than in the following year. Similarly the effect of the nitrogen in increasing the nitrogen content of the herbage was more pronounced in the wet than in the dry season. The yield of crude protein per acre in the nitrogen-treated herbage was double that of the non-treated herbage in 1930 and 47 per cent. higher in 1929, the actual yields of crude protein being 13·7 cwts in 1930 and 5·0 cwts in 1929. Digestibility trials gave high figures for both types of herbage, with no significant difference between them.

The effects of nitrogen are summarised as follows :—

(1) The production of grass at an earlier date than normal.

(2) Increase in total yield of dry matter and crude protein per acre.

(3) A suppression of the normal habit of growth of the herbage. The rapid increase to a maximum at the flush period, followed by a rapid falling off in the productivity of non-nitrogen-treated pasture, is replaced by a more uniform rate of growth.

(4) Recovery is accelerated after the mid-season depression of growth.

(5) A still more uniform distribution of growth after the turn of the year in August and September.

(6) The maintenance of autumnal growth at a higher level than that of non-nitrogen-treated grass.

(7) An increase in the protein content of the herbage more particularly at the most critical periods when the percentage in the non-nitrogen-treated grass falls to a very low level.

(8) High digestibility of the herbage throughout the season.

A side-issue of interest dealt with in these tests is the amount of food consumed by the sheep grazing the plots, the data indicating that a mature sheep of 120 to 140 lbs. live weight eats about 3½ lb. of dry matter per day, and that a lamb of 80 to 90 lb. will eat 2 lb. of dry matter per day in the form of grass, these amounts being in close agreement with the standards commonly assumed for such animals. The daily live-weight increases of the sheep were similar on both types of herbage, indicating that the gains per acre were proportional to the bulk of herbage produced under the two systems.

A further report (Ref. 61) from the same source deals with data on the mineral content of herbage from three other "Intensive System" tests. The mineral content of "intensive pasture" was found to be equal to that of the best type of pasture produced by other systems of management, and superior to that of average good cultivated pasture in Great Britain. The seasonal variations of the mineral ingredients depend chiefly on the climatic conditions. The effect of drought at one centre was to lower the percentages of soluble ash, phosphorus and potash. The proportion of phosphorus varied with that of nitrogen, and the proportion of potash with that of the soluble ash.

Passing reference only can be made to the activities of

Fagan and his colleagues at Aberystwyth, which continue unabated. Their recent reports (Ref. 62, 63, 64) deal with the effect of manures on the nitrogen and mineral content of the herbage of pastures of different types under ordinary management. They supply also further data on the composition of different species and types of plants, including white clovers, Italian rye-grasses, and—in some respects most interesting of all—an extensive series of the miscellaneous "herbs" of pastures. The object of bringing the last-named under examination was to obtain, if possible, some indication as to why stock are partial to these herbs at certain seasons of the year. While winter greenness is an undoubted attraction; and might account for the consumption of some of them which are available when grass "keep" is scarce, it does not account for the preference often shown by stock for such herbs as the daisy, cat's ear and rib grass where "keep" is plentiful. The analyses reported indicate that the characteristics of the leaves of most of the herbs consumed, and especially those sought for by stock, are richness in protein and mineral content, suggesting an example of intuitive wisdom on the part of the stock in their selective grazing.

Brief reference may also be made to the Report of the Pasture Sub-Committee of the Advisory Committee on Agricultural Science (Ref. 65). Investigations initiated by this Sub-Committee were designed to obtain in the first season (1928) yield curves from as large a number as possible of different types of pasture typical of their district, and then in subsequent seasons to ascertain the effect of manurial treatment in increasing the productivity of these pastures, and in spreading the produce more evenly over the grazing season. The experimental centres were distributed over England, Wales and Scotland and the observations covered the four years 1928–31. The results show a wide range of production from the untreated plots at the different centres in any one season, as well as in the distribution of the growth over the season at the different centres. The variations in yield of dry matter at each centre from season to season were, to a certain extent, correlated with the rainfall. The application of fertilisers had a very marked beneficial effect on the total produce for the season, but did not seem to exercise any definite influence on the distribution of the growth over different parts of the season. The produce from the fertilised plots showed an increase in the protein content of the dry matter in 1929, and increases in the protein, lime and phosphorus content of the dry matter in 1930 and 1931.

The Canadian experiments of Shutt (Ref. 66) outlined in previous Reports have been continued for a fifth year, with

results entirely confirmatory of previous conclusions, and of English work, as to the effectiveness in producing "high protein pasture" of cutting or grazing at short intervals. "It is in this matter of protein production that the rotational scheme of pasture management finds its distinguishing and most valuable feature."

Australian pasture studies at the Waite Institute have been reported by Richardson (Ref. 67), Dutch analyses by Sjollema (Ref. 68), and Norwegian observations by Isaachsen (Ref. 69), but do not require more than passing reference here. In a further paper (Ref. 70) Sjollema discusses the adequacy of the mineral composition of young pasture and fodder for the needs of milch cows. He points out that, in addition to the excessive protein consumption involved in grazing young grass, there is also too much potassium relatively to calcium, phosphorus and sodium, and often large quantities of nitrate. These defects are probably intensified by heavy manuring with nitrogen and potash salts. Rational manuring and the presence of clover would give pasture of better balanced mineral composition. In winter the calcium balance is often negative and the supply of phosphorus is as a rule high. Spring calved cows, on pasture, show negative balances of both calcium and phosphorus. In autumn the balances become positive, but in winter with a Ca : P ratio in the diet of about 1 : 4 or 1 : 5 they may again become negative. Feeding hay of good quality with a Ca : P ratio of about 2·2 : 1 should effect improvement in this respect. In winter negative sodium and chlorine balances may be expected; hence supply of common salt is desirable. Grass has an excess of basic over acid ingredients, but it is uncertain whether the base-forming properties of the grass influence the absorption of calcium and phosphorus.

In view of the proposals made from time to time for the conversion of young grass into dried grass cakes for use in winter feeding it will be appropriate to include in this section of the Report a reference to the work of the Jealott's Hill staff on the digestibility and feeding value of fresh grass, artificially dried grass and artificially dried hay (Ref. 71). The results indicated that the process of drying grass in a band drier by heated air at an inlet temperature of 200° C. does not appreciably affect the digestibility of the different constituents of the grass, with the possible exception of a slight lowering of digestible crude protein. In a second test, however, in which the inlet air temperature was 600° C., there was a definite lowering of digestibility all round, and notably with regard to the protein.

The hay tests were made with a sample of hay of excellent quality made by a process of artificial drying in which a current

of warm air is blown through the grass in a stack, the air being heated by a system of hot-water pipes round which the stack is built. The resultant material proved to be of high digestibility, and was of much greater feeding value than good meadow hay or seeds hay. It was made at a season of the year when ordinary hay-making conditions were poor. The report closes with the comment that "unfortunately no data are as yet available to allow of comment on the economic aspect of the process."

The section may be concluded with a reference to the second Report on Pasture Research issued by the Empire Marketing Board (Ref. 72). This Report summarises briefly the latest information on grassland research, both chemical and botanical, and indicates with emphasis the economic importance of grassland to the Empire.

XI.—Foods and Feeding Practice.

Under this heading a number of items relating to the composition of foods and practical feeding tests may be summarised.

Oats.

In connection with the Cambridge digestion trials already referred to (Ref. 42) two practical feeding tests were also carried out with pigs. In these trials "farm-ground" oats were compared on the one hand against barley meal, and on the other against "middlings." The average results expressed in terms of pounds of meals consumed per 1 lb. of live-weight gain were as follows :—

	Trial A. Lb.	Trial B. Lb.	Average. Lb.
Lot I (no Oats) . . .	4·16	4·30	4·23
Lot II (Oats replacing Barley)	4·20	4·43	4·31
Lot III (Oats replacing Middlings)	4·04	4·44	4·24

The differences shown are well within the normal range of variation but it would be unsafe to draw the apparent conclusion that farm-ground oats, barley meal and middlings are practically equal in feeding value. It is more probable that there are differences which are too small to be measured in trials with ten pigs per lot as in this case. For rationing purposes it will be safer meanwhile to use the relative values based upon the content of digestible ingredients of the three foods, which indicate that farm-ground oats should on the average be roughly equal to middlings and some 10 to 15 per cent. inferior to good barley.

Similar caution must be observed in interpreting the results of tests with oats and barley for pigs published from the Oregon Experiment Station (Ref. 73), which are given as follows in

terms of relative values as compared with that of whole dry grain taken as 100 :—

	Oats.	Barley
Whole grain soaked . . .	99·6	90·1
Coarsely ground grain . .	103·6	109·6
Finely ground grain . . .	112·7	113·1
Steam-rolled grain . . .	97·6	116·5

Maize.

A valuable report on the composition of maize, with special references to variations in its content of Vitamin A, has been published by Fraps from the Texas Experiment Station (Ref. 74). This report contains a review of the literature dealing with the Vitamin A content of maize, a discussion of the relative merits of the "ration method" and the "unit method" of determining Vitamin A, along with tabulated data obtained by the unit method for the content of Vitamin A in yellow, red, variegated, and white maize. The relation of Vitamin A to heredity, and the variations according to season and locality are discussed, and a few data on the distribution of this vitamin in the milling products of yellow and white maize are given. In addition the report contains proximate and mineral analyses of varieties of maize grown in different parts of Texas, and data on the correlation of the protein content of maize with rainfall in different seasons.

In 39 samples of yellow maize of different varieties grown in different localities and during three seasons the number of "units" of Vitamin A found per gramme of maize varied from 2·5 to 8. An average figure of 5 units may be taken for practical purposes. In 18 samples of one variety each of variegated and red maize, the variation found was from 0·9 to 2·9 units. Both varieties not only contained less Vitamin A than yellow maize, but were also more variable. White maize contained so little Vitamin A that the amount could be estimated only approximately. In crosses of white and yellow maize the units of Vitamin A were found to be approximately in proportion to the number of genetic factors for yellow endosperm present.

No significant varietal differences were found in the proximate or mineral analyses, but maize grown in different localities showed variations in content of lime and phosphoric acid, and even greater variations in protein. The latter varied not only with the locality but also with the season, and showed a statistically significant correlation with the rainfall.

Palm Kernel Cake.

Continental experiments on the use of palm kernel cake for milch cows have always been very consistent in indicating that

it has a favourable specific effect in raising the percentage of fat in the milk. Two further examples are to hand and may be noted.

In a test reported from the Berlin Institute of Animal Breeding (Ref. 75) seven cows received mixed concentrates in proportion to milk yield, these including from 4·6 to 8·6 lb. of palm kernel cake per day. All showed an increase in fat-content of milk, varying from 0·2 to 0·7 per cent., with an average of 0·4 per cent. In previous experiments an average increase of 0·34 per cent. had been obtained provided not less than 4·4 lb. (2 kgs.) of palm kernel cake was given per head per day. The amount of the increase was primarily determined by the individuality of the animal, subject to the above-named minimum supply of the food. In neither experiment was there any significant effect on the yield of milk.

From Holland comes a report (Ref. 76) on two experiments comprising 52 tubercle-free cows in full milk. The palm kernel cake used contained about 7 per cent. of oil and the comparison was made of 2·4 kg. (5·3 lb.) of this against 2 kg. (4·4 lb.) of a mixture of groundnut meal and maize meal calculated to supply the same amounts of starch equivalent and digestible protein. In each experiment the fat yield and the percentage of fat in the milk were appreciably increased by the palm kernel cake, the average increase in fat percentage being $0{\cdot}44 \pm 0{\cdot}025$.

The improvement was not merely transient, but always persisted unabated for the full experimental period of eight weeks. No appreciable effects were recorded on the milk-yield, total solids and protein content of the milk, or on the live-weights of the cows.

Little experimental work on this subject has been carried out in Great Britain, and that only on a small scale. The results, such as they are, lend little support to the claims based upon the Continental work, but in view of the practical difficulties of maintaining high quality in milk it would seem desirable that the possibilities of palm kernel cake in this direction under British conditions should be submitted to a crucial test on an adequate scale.

Malt Culms.

Tests of the merits of this once-popular food have been carried out in Ireland with calves, yearling cattle, fattening cattle and dairy cows (Ref. 77). In each case the comparison was made with palm kernel cake, a food containing approximately the same proportions of protein and fibre as malt coombs. From the data obtained the conclusions are drawn that malt culms are about equal to palm kernel cake for calves and yearling cattle, but slightly inferior to it for fattening 2–3-year-

old cattle and for milk production. Some further allowance ought, perhaps, to be made for the superior palatability and "spicing" value of malt coombs when used as an adjunct to grain of moderate quality.

Fish Meal.

American experiments (Refs. 78, 79) with seven different fish meals have shown that the method of manufacture may affect both the content of vitamin A and the biological efficiency of the proteins. The types of meal used were (1) vacuum-dried white fish-meal consisting of the heads, tails, fins, and adhering flesh, of white fish (but not the entrails), obtained as a by-product of the filleting of fish, and dried in a vacuum at 105°F.; (2) flame-dried menhaden meal, obtained by drying the whole fish, less most of the oil, by exposure to direct heat at about 500°F.; (3) steam-dried menhaden meal, a product experimentally produced by the U.S. Bureau of Fisheries, and which was more carefully handled throughout the manufacturing process than the flame-dried meal, as well as dried at a much lower temperature. In contrast to the white fish meal which is made from non-oily fish, the menhaden is an oily fish, and a portion of the oil is removed by cooking and pressing before drying which still leaves from 4 to 12 per cent. of oil in the dried product. The meals tested contained 58–62 per cent. protein, whilst the oil ranged from 2–6 per cent. in the white fish meal to 11·8 per cent. in the steam-dried menhaden meal. The vacuum-dried white fish meal proved superior to the rest in digestibility, protein-efficiency and Vitamin A content. The steam-dried meal was superior to the flame-dried meal in protein-efficiency, but neither contained any appreciable amount of Vitamin A.

Meat Meals.

Similar studies with meat meals have been carried out in New Zealand (Ref. 80). Special interest attaches to the difference in value found between the proteins of meat and those of bone. In these experiments the biological values of the proteins of four meat meals containing no bone were so much higher than those of four meat meals containing a large proportion of bone that it was necessary to use from 30 to 40 per cent. more of the latter class of meal to cover the protein requirements. This must tell in practice against the economy of the use of low-protein meat meals or meat-and-bone meals.

The Vitamin A content of two of the meals was such that when fed at a 10 per cent. protein level they required no vitamin supplement. One meal contained a little Vitamin A, but required supplement, whilst two meals were entirely devoid of this vitamin. Five meals were found to be devoid of Vitamin

B. Purified tallow of the two meals rich in Vitamin A contained little or no vitamin, indicating that the destruction of the vitamin takes place during purification of the tallow and not during the process of manufacture of the meal. Tallows from four of the meals were found to contain appreciable amounts of Vitamin D. Judged by nutritive value there appeared to be little difference between meals manufactured by the wet and by the dry process, and the conclusion is drawn that the value of the meals is determined chiefly by the nature and proportions of the raw materials used.

Dried Sugar Beet Pulp.

The establishment of the beet sugar industry in this country has added the dried extracted pulp to the list of available feeding-stuffs and created a demand for reliable information as to its value, both in the plain and in the molassed form, which has led to the carrying out of a number of feeding trials.

At Cambridge a comparison has been made (Ref. 81) of the relative value of oats, molassed beet-pulp, and plain beet-pulp for the fattening of store cattle. At the Hertfordshire Farm Institute a similar comparison has been made with younger cattle fed for " baby beef " (Ref. 82). The general conclusions are the same in each case, namely that, apart from a little advantage of the molassed pulp in palatability, the two types of pulp may be regarded as equal in value, and approximately equal to crushed oats in general food value. With the smaller animals up to 10 lb. per day, and with the larger animals up to 15 lb. per day of either type of pulp was used without trouble.

In an experiment at the Staffordshire Farm Institute (Ref. 83), a similar comparison of molassed beef pulp against oats was made with dairy cows, and here again the same conclusion was reached.

In experiments with pigs at the Harper Adams Station (Refs. 9, 84) plain beet-pulp, supplemented by a little soya meal, proved an effective substitute for " sharps " up to a limit of about 20 per cent. of the ration. Beyond this point, undue laxative effects began to develop and the rations became too bulky.

Dried Milk Products.

A report from the Iowa Experiment Station (Ref. 85) contains matter of interest on the value of *dried buttermilk* for growing and fattening pigs. The dried buttermilk was tested against and in combination with meat meal tankage. Adding dried buttermilk to a ration of maize, tankage and salt was found to increase the rate of live-weight gain and to

decrease the amount of feed required per unit of gain when the proportion of dried buttermilk to tankage was fairly high. The use of the buttermilk also increased the efficiency of the total protein in the ration. The protein was used more efficiently in a buttermilk-maize ration than in a tankage-maize ration. The lots receiving buttermilk consumed more water daily and required more water per 100 lb. of gain than did the control lot. It was found in this test that 100 lb. of dried buttermilk was approximately equal in relative feeding value to about 75 or 80 lb. of tankage from the standpoint of live-weight gains produced, when used as a supplement to maize. On the average 100 lb. of it replaced 75 lb. of tankage plus 7 lb. of maize in producing equal gains.

In a Canadian experiment (Ref. 86) *dried skim milk* powder was compared with a protein-mineral supplement, consisting of a mixture of tankage, linseed meal, fish meal, bone meal, ground limestone, salt, and ferric oxide, both being fed along with maize meal and wheat middlings. The pigs in the milk lot made an average daily gain of 1·54 lb. per head, or 50·0 lb. for each 100 lb. of feed eaten. In the other lot the average daily gain was 1·42 lb. per head, and the pigs gained 45·4 lb. for each 100 lb. of feed consumed. After making necessary allowances there was a nett advantage in favour of the skim milk of 1·3 lb. of gain per 100 lb. of feed consumed, or in other words the skim milk powder was 2·9 per cent. more efficient for producing gains than the protein-mineral mixture.

Mangolds and Swedes.

New data on the composition and digestibility of mangolds have been given in an earlier section. A few observations from the West Virginia Station (Ref. 87) on the changes in composition of mangolds and swedes during storage may be added. These observations which extended over three years showed that mangolds and swedes undergo certain changes during storage, some of which are quite regular whereas other are irregular. The most noticeable, as well as the most consistent, change was continuous loss of moisture with accompanying increase of the percentage of dry matter. During the first three months of storage the dry matter content of mangolds had increased 2·58 per cent., and that of swedes 2·73 per cent. This was equivalent to relative gains of 32·7 per cent. for mangolds and 30·5 per cent. for swedes. The changes in the composition of the dry matter itself varied as between the two types of roots and also for each from season to season. On the average of the three years the most pronounced changes in the relative composition of the dry matter of swedes was loss of carbohydrates and, to a lesser extent,

of crude protein. With mangolds, on the other hand, the greatest relative change appears to have been a loss in crude protein. High dry matter was usually accompanied by low protein in mangolds, but no such relation could be traced in the case of swedes.

Potatoes.

Three series of pig-feeding tests with cooked potatoes are reported from Denmark (Ref. 88). In the first experiment (250 pigs), in which a basal ration of grain and skim milk was used, cooked potatoes replaced part of the grain mixture to the extent of 11, 22, 33 or 43 per cent. of the ration. Up to 33 per cent. the rate of growth was practically the same as on the basal ration, but when the proportion of potatoes was increased further a slightly lower rate of gain was recorded, owing to lower total food consumption due to the bulkiness of the ration. These results are entirely in accord with those obtained in similar tests at the Harper Adams Station (Ref. 9).

In the second test, additional protein (soya meal, blood meal, meat meal) was provided with potatoes fed at the 23 per cent. and 43 per cent. levels. There was a slight increase in rate of growth which was most definite in the early stages.

The third test, in which the initial and final levels of protein were varied with the same percentage of potatoes throughout, showed only small differences. The best results were got with initial levels of 97 gms. and 112 gms., and final levels of 73 gms. and 72 gms. of digestible protein per feed unit. The quality of the flesh and firmness of the fat were definitely improved with increasing proportion of potatoes fed.

Pasture.

Danish experiments on the digestibility of grass and hay (Ref. 44) have been summarised in the section dealing with pasture experiments, but further observations from the same source on the need for supplement feeding to milch cows on pasture may be summarised here. It is held for Danish conditions that with good, young pasture, rich in clover, cows giving up to 20 or 25 kg. (44–55 lb.) of milk with 4 per cent. fat require nothing in addition to the pasture, whereas with old and coarse grass a supplement of concentrates may be required for yields above 10 kg. (22 lb.) milk. The best economic return was given by feeding 0·5 kg. (1·1 lb.) concentrates for every 2·5 kg. (5·5 lb.) of "standard" (*i.e.* containing 4 per cent. fat) milk over the level indicated by the quality of the grass, the concentrate mixture containing about 20 per cent. digestible protein. It is recommended that the mixture should contain considerable proportions of coconut and palm kernel cakes, in

view of Danish experience that they raise the fat content of milk given by cows on pasture, without any harmful effect on the consistency of the butter.

Silage.

The interest in acid methods of ensilage which has been prevalent on the Continent during the last few years, has now spread to this country and in particular the method developed by the Finnish expert, Dr. Virtanen, and familiarly referred to as the A.I.V. method, is attracting attention. For those interested a descriptive article on the method (Ref. 89) prepared by the Imperial Bureau of Animal Nutrition will be helpful.

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FARM IMPLEMENTS AND MACHINERY

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I.—Testing of Agricultural Machinery.

The First Report of the Agricultural Machinery Testing Committee (Ref. 1) gives an account of the origin of the Ministry of Agriculture's Testing Scheme and the work which has been done in connection with it. Reference is also made to the existing arrangements for testing agricultural implements in other countries. The section which deals with the problems arising out of the tests discusses some points of general interest.

A number of tests have been carried out since the publication of the Report, but on the whole the scheme does not yet appear to attract as much attention from manufacturers as it deserves.

In connection with the testing of tractors it is interesting to note that a Swedish testing station has now constructed a dynamometer car similar to those used in this country (Ref. 2).

II.—The Spread of Power Farming.

The increased application of power to agriculture is probably engaging more attention at present in Great Britain than all other branches of research in agricultural engineering. While, however, many of the problems involved belong definitely to engineering, the standpoint from which the results have to be judged is primarily an economic one. The real trial, whether it be of a new machine or of a new application of an existing one, must be carried out with normal agricultural labour as part of the everyday working of a commercial farm. A great deal of work of this kind has been done during the past year, and is continuing. There is, however, one difficulty, that of recording and publishing the results obtained. So far the results of the work have been published in two ways. First, conferences have been arranged by various bodies, at

each of which papers have been read by practical farmers engaged in increasing the use of power on their farms. Provided that full reports of such conferences are available to everyone interested, their value to the general farming community is very great, and it is to be hoped that they will continue to be arranged.

The second way in which the appropriate records are being collected and published is by means of a "Survey of Mechanised Farms" which was begun at the end of 1930 by the Institute for Research in Agricultural Engineering. A number of the more advanced farms in the country are being regularly visited and all possible details as to their working are being recorded. Information about specific operations drawn from various farms is thus being collected and is to be published from time to time.

In the work on Power Farming which is being done on the general lines indicated above, two main lines of enquiry are followed. The first concerns itself simply with making increased use of mechanical power to lower the cost of certain necessary operations, such, for example, as the preparation of the seedbed. The second line of enquiry, on the other hand, seeks to discover how, possibly by eliminating certain operations the cost of which cannot so easily be lowered, the existing rotations can be modified so as to take the fullest advantage of the benefits of mechanisation. In a country whose agricultural system depends very largely on relatively small mixed farms the second line of research is undoubtedly the more important, since it will ultimately determine the scope of power farming in Great Britain. A great deal of discussion on this subject has already taken place. Orwin (Ref. 3) considers that while there is an ample field for development, the greater labour cost involved by the handling of stock will always restrict true power farming to the arable districts. He mentions two cases where mechanisation may save arable land from going out of cultivation; the light chalk lands where low yields make low costs of production an essential to success, and some of the strong wheatlands where economy demands more power than horses can supply.

Watson (Ref. 4), on the other hand, discusses in some detail the possible application of mechanised methods to the larger types of mixed farm. He envisages a cereal acreage large enough to involve the use of a Combine Harvester worked in conjunction with either grassland sheep or out-wintered cattle by means of two year leys and suitable forage crops. The possibility of combining livestock with power farming is also discussed by Nevile (Ref. 5).

A general review of the progress which has already been made

in mechanised arable farming has been given by Newman (Ref. 6) in a paper which includes a number of actual examples taken from farms in this country. Three main lines of advance are described. The first and perhaps the most important of these is the increased efficiency of the modern tractor, which has disposed of the need for keeping horses and horse equipment available for use in emergency. The second advance lies in the provision of implements wide enough to make full use of the drawbar power of the tractor. Only by the use of such implements can the greatest reduction in overall costs of working be achieved. Some of the figures given are very striking, both from the point of view of speed of working and from that of cheapness. A typical case is that of 275 acres of wheat which were ploughed and planted in six weeks at a total cost, excluding seed, of 11*s*. per acre. The third feature, the speeding up of the harvest by means of the Combine Harvester, is dealt with later in this article. In a further paper the same writer (Ref. 7) extends his review to take account of modern methods of grassland farming and gives a fairly full account of the working of a 1,000 acre grass farm, including a schedule of the machinery used. Mention is also made of the possibility of further adaptation of the newer methods to the growing of roots and potatoes.

More or less detailed accounts of the working of their own farms from the mechanical point of view have been given by Dudley (Ref. 8) and Nevile (Ref. 9). The former writer lays particular stress on the economies effected by the use of disc ploughs, particularly in the making of fallows, while the latter gives much useful information about general tractor working.

All the writers mentioned so far have dealt with power farming on relatively large acreages, generally upwards of 300, and their conclusions therefore are not immediately applicable by the majority of British farmers. In a very interesting contribution to a recent discussion, however, Wolton (Ref. 10) deals with mechanisation from his own point of view, that of the farmer of about 150 acres. He points out that the terms "Mechanisation" and "Combine Harvester" are not inseparable and endeavours with some success to show that "the small farmer having about 150 acres, half of which is arable, need not fear this new development, and that mechanising his farm should be of equal advantage to him as to the large scale farmer."

III.—Harvesting.

The above remark on the Combine-Harvester was no doubt inspired by the fact that this implement figures very largely

in each of the accounts of the working of arable farms that have been referred to. A general account of the performance of the ten Combine Harvesters which worked in England during the 1931 harvest is given by Cashmore and Newman (Ref. 11). During its first two seasons in England the Combine Harvester was favoured by abnormally dry harvest weather. In 1930 conditions were not so favourable, while the performances of several of these machines during 1931, in what was probably the wettest harvest for fifty years, has shown beyond doubt that they will become a permanent feature of British agriculture of the future. In the case of malting barley it is even claimed that in a wet season the method shows a definite advantage over the use of the binder. Perhaps the most striking case quoted is that of a farm in Hampshire, where, following a rainfall of over an inch before noon, 63 sacks of wheat were cut and threshed successfully on the same day. This wheat when threshed contained over 30 per cent. of water, and the fact that this was reduced on the farm to 15 per cent., without difficulty, indicates that the problem of drying "Combined" grain has not been neglected. Another interesting feature of the 1931 harvest was that for the first time a Combine Harvester was worked by a contractor and gave every satisfaction in cutting nearly 200 acres. There should be considerable openings in many districts for harvesting by contract.

Apart from the necessity on economic grounds of having a rather large acreage to deal with, the greatest difficulty in the way of a very large extension of the use of Combines is the problem of dealing with long straw. Various methods of tackling this problem are dealt with in the paper referred to, but it is recommended that the binder should be retained in districts where there is a good market for long straw.

In stationary threshing particular care is taken over levelling the machine. The Combine, on the other hand, frequently has to thresh while passing over unlevel ground. There are, of course, hillside Combines available, fitted with levelling adjustments, but on account of their extra cost they are much less common than the ordinary Prairie type. The grain losses which may result from the use of the latter type of machine on cross gradients are discussed by McKibben (Ref. 12). He refers to some experiments carried out in Pennsylvania, which showed that, in the case of the particular make of Combine used, large losses of grain might result from even a small cross gradient if the straw was long and heavy. Reducing the amount of straw put through decreased these losses. The paper goes on to discuss the distribution of weight in long-strawed cereals and points out that the lower portions of the straw are the heavier. Apparently the moral which is intended to be drawn

from this conclusion is that cutting a slightly higher stubble may make things very much easier for the Combine. In this country, on the other hand, a rather different point of view may be taken: that leaving a longer stubble means losing more straw than one might expect.

While on the whole it may be concluded that the Combine Harvester has earned its place on the larger cereal farms, it does not follow that its use will become general on the mixed farms of the country. Bomford (Ref. 13) raises several objections to its use and considers that the loss of straw alone is a serious disadvantage. The very striking figures given by Hosier (Ref. 14), however, suggests that even without the Combine the costs of harvesting and threshing can be considerably reduced by proper organisation of the work. In the case he describes 36 acres of oats were grown, harvested and threshed at a cost of under £100, the straw alone being sold for £114. A similar conclusion is to be drawn from a German paper on harvesting, in which Zander (Ref. 15) describes threshing from the stook with the aid of a low harvesting wagon and compares the costs with those of Combine harvesting. There was little difference between the capital costs involved by the two systems and it is suggested with regard to working costs that the expense of dealing with the straw behind a Combine may offset any advantage which is gained by avoiding reaping and stooking. Derlitzki (Ref. 16) also describes labour-saving harvesting methods in which a special low loading wagon figures prominently. A note by Rosam (Ref. 17) describes another method of harvesting which is being tried in Czechoslovakia. An ordinary binder is equipped with an auxiliary cutting device, which removes the heads from the standing corn. These are delivered into a light wagon which is attached to the outfit, while the straw is handled by the binder in the ordinary way. It is claimed that the method reduces the "peak load" of harvesting, since only the most easily lost or damaged portions of the crop are removed from the field in the first operation. The straw is stooked and is retrieved later when the grain has been put safely under cover. It is further claimed that the subsequent threshing of the grain is rendered easier, since there is much less bulk to deal with and the threshing machine can, if desired, be fed by means of a blower. Another advantage claimed, which hardly applies in this country, is that the harvested grain cannot be stolen from the fields !

IV.—Haymaking.

Although no research papers dealing specifically with haymaking have been published in this country during the year

under review, very striking developments are taking place, particularly in the final carrying of the crop. In America a preliminary trial has been made of a new type of mower, primarily intended for dealing with lucerne (Ref. 18). The machine consisted essentially of a grain binder in that it was fitted with a cutter bar, reel and platform of the ordinary type. The platform canvas, however, delivered the cut material to a pair of power-driven rubber-covered rollers between which it was passed. The stems were thus crushed and the removal of moisture from them was accelerated. Over-drying and consequent loss of the leaf could thus be avoided. In the first test in which this method was compared with the normal one it was found that the crushed hay dried naturally to 15 per cent. moisture content in 23 hours, as compared with 49 hours for the uncrushed material. In the second trial the weather conditions were less favourable. The crushed hay, however, took about the same time to dry as in the first trial, while the hay cut in the normal way contained 50 per cent. moisture after three days. Determination of the losses due to shattering were not made, but these are to be studied this year. A new model of this machine has since been produced, in which the rollers are parallel to and of the same width as the cutter bar, the crushed hay being deposited on the ground from which it was cut.

A German paper (Ref. 19) analyses the power absorbed in grass mowing. With an old machine well lubricated only 22 per cent. of the total power was used in the actual cutting. It is surprising to note that when a new oil bath mower was tried, it was found that the power requirements did not differ appreciably from those of the old machine.

V.—Tractors.

One of the chief difficulties of estimating the costs of tractor operation in Great Britain lies in the small number of tractors available for study in any district of reasonable size. It is particularly difficult to form any valid estimate of the probable useful life of the machine and therefore of the allowance which should be made for interest and depreciation. The hours worked per tractor, too, vary so much from farm to farm that records of a large number of farms are essential before any reliable average can be arrived at. A great deal of information of this kind is given by Schwantes and Pond (Ref. 20) in a paper which deals with a comprehensive survey of tractor work carried out during 1929 in Minnesota. Since there is a tendency in this country to regard all tractor farming in the U.S.A. as being carried out on a scale out of all proportion to average British practice, it is interesting to note that the conditions obtaining

on the farms included in this survey appear to be not unlike those which would be found in British arable districts. Thus, for example, the average area of the 291 farms considered was 355 acres, while the average size of field was 24 acres. Judging from the figures given for the rates at which the different arable operations were performed by tractors of various sizes, the land would seem to correspond to the lighter British soils. The total number of tractors at work was 314, so that very few farms had more than a single machine, while in addition each farm on an average worked 7 horses. From the point of view, therefore, of complete replacement of horse labour by tractor power, the Minnesota farms at the date of the survey were not more advanced than our own. On the whole, the conclusions reached should apply fairly well to tractors in Great Britain. Almost all the tractors concerned were of the ordinary wheeled type and what American nomenclature terms "two-plow" and "three-plow" machines were about equally common. These classes correspond roughly to tractors of 10 and 15 drawbar horse power respectively. The most interesting, perhaps, of the conclusions reached relates to the probable life of the machines. The average age of the tractors was rather over 4½ years, 6 per cent. of them being over 10 years old. From the results of an estimate which each tractor operator was asked to give of the useful life of his machine, it was deduced that the probable useful life of a wheeled tractor might be taken as 10 years. It is stated that on an average each operator had had 8 years of tractor experience and the authors, therefore, conclude that the above estimate is likely to be reliable. The number of hours worked per year by the various machines varied enormously, from no more than 30 in one case to over 2,600 in another. Since in one of the papers previously referred to (Ref. 6) it is reported that two British tractors did 3,000 hours' work each during last year, even the highest Minnesota figure does not appear to be excessive. The mean annual hours of work came out at 417. From the data collected from a detailed questionnaire filled in by each farmer, an estimate of the overall costs of working was made. With the 10 h.p. machines the total cost was about 4*s.* 6*d.* per hour. Fuel, oil, repairs and service amounted to 2*s.*, while labour and interest, depreciation, etc., came out at about 1*s.* 3*d.* each. Depreciation was based on a 10-year life, while interest was charged at 8 per cent. Fuel and labour were charged at about 8½*d.* per gallon and 1*s.* 3*d.* per hour respectively. With the 15-h.p. tractors the total cost was about 5*s.* 8*d.* per hour: a 50 per cent. increase in output at an additional cost of only 28 per cent. One other interesting conclusion may be noted, namely, that the operating costs, whether of fuel alone or the overall total, did not vary significantly with the

age of the tractors considered. There is a great deal of further information given in the paper, which both Agricultural engineers and farmers would do well to study.

The Agricultural Economics Research Institute (Ref. 21) gives the average hourly cost of working, excluding labour, of 9 tractors in the Oxford Province during 1930 as *2s. 5d.* Consideration of the individual costs given suggests that this figure may be too low. In the case of two of the tractors, for instance, the cost of fuel and oil per hour comes out at considerably less than the lowest figure for similar tractors recorded in the World Tractor Trials, which were held during the period for which these costs are given. Again, the allowances for depreciation given for some of the tractors are very low. This may perhaps be justified on the ground that the tractors are so old that allowances made under this head in previous years have practically written off their first cost, but in this case the resulting figures are not likely to apply in the case of the average user.

Every year a new discussion arises as to the proper speed at which tractor ploughing and cultivation should be done. In the course of a recent discussion Keen (Ref. 22) quotes the well-known Rothamsted experiment which showed that an increase of 60 per cent. in ploughing speed was accompanied by an increase of only 7 per cent. in draught of the plough, and goes on to express the opinion that "this conclusion . . . means that the development of the tractor and of tractor-drawn implements should aim at the highest possible speed consistent with mechanical reliability." Engineers are not likely to agree with this statement. An increase in draught, however small, means a corresponding increase in the energy which the tractor has to exert in doing a given piece of work, and until it is shown that some advantage is gained by the different effect of the implement on the soil, the extra energy must be regarded as sheer waste. Judging from the report of a recent Conference (Ref. 23) Italian opinion also favours increasing the working speeds of tractors. The suggestion is made that they should be raised to from 6 to 7½ m.p.h. The results of British drawbar tests of tractors (Ref. 24) do not appear to support this recommendation, since they show that in almost every case there is a marked decrease in power output at higher speeds. A further point is that modern research shows that the most important factor in determining wear, particularly of parts subjected to dry friction, is speed of rubbing. Increased speed of rubbing means greatly increased wear. More than one user of tracklaying tractors, for instance, has found the wear of the track pins to be considerably increased by prolonged running on top gear. It is highly probably that the wear of

plough shares, cultivator tines and similar parts would be affected in the same way. On the whole, such British data as are available suggest that there is little to be gained from increased speed of working, provided first that implements can be obtained large enough to load the tractor fully on its lower gears and, secondly, that in the case of wheeled tractors the drawbar pull at the lower speed is not too great for the wheels to transmit. The Italian paper also advises that wheel diameters and widths should be increased and that the centre of gravity should be brought within a few centimetres of the ground. These proposals do not appear to fit in with modern attempts at turning the tractor into a general purpose implement, quite apart from the difficulty of bringing about the first and last of them in the same machine. A German paper (Ref. 25) also suggests that tractor speeds should be increased, but on the ground that better work will be done.

VI.—Manure and Seed Sowing.

In the last volume of *Agricultural Research* the results of some tests of drills were mentioned as indicating that the force-feed drill was preferable to the cup-feed type for corn drilling. In the paper then quoted it was mentioned that certain experimental drills, which aimed at giving greater uniformity in the field, were being tried at some research stations. One of these drills has since been subjected to an exhaustive series of tests (Ref. 26). The results were disappointing since, although the inter-coulter performance was reasonably good and could be improved by careful adjustment, the performance along the rows showed no superiority over other force-feed drills. It is mentioned, however, that field trials with the same drill have indicated some superiority.

A paper by Kühne (Ref. 27) summarises the experiments carried out by Heuser in 1925–27 to compare drilling with "single-seed sowing" or dibbling. The original experiments gave an average yield of about 40 bushels of wheat per acre on the drilled plots and this yield remained practically constant when the rate of seeding was varied between $1\frac{1}{4}$ and $2\frac{1}{2}$ bushels per acre. In the same experiments single seed sowing at a rate of $1\frac{1}{2}$ bushels per acre, the seeds being spaced at about 1 inch apart, gave yields of about 45 bushels per acre, an increase of 5 bushels. In similar experiments carried out in Upper Bavaria in 1930, dibbling gave an increase in yield of about 4 bushels per acre. The straw from the dibbled plots is described as being stiffer and longer than that from the controls, and it is remarked that in a season of exceptionally heavy rainfall the storage qualities of both grain and straw were superior. The

paper goes on to point out that single seed sowing in this connection must not be confused with those methods of spaced drilling in which a considerably reduced quantity of seed is used. The machine used by both Heuser and Kühne sowed quantities of seed comparable with the lower rates of seeding used in ordinary drilling, and the essential feature of the method is simply more even spacing. It appears, then, that these workers have achieved something like the perfect seed spacing which Engledow and others have shown to be desirable. Unfortunately, however, no particulars are available to indicate whether the machine used is a practical proposition from the point of view of the farmer.

Two reports of trials of fertiliser distributors were referred to in last year's *Agricultural Research,* and it was mentioned that both of these drew attention to the absence of lateral movement of the fertiliser in the soil. A German worker (Ref. 28) has recently used an ingenious device to study the effect of various implements on both vertical and horizontal distribution. The fertilisers were impregnated with a solution of anthracene and were then sown by standard machines. After various cultivating operations had been carried out samples of soil were removed in boxes of about 12 ×12 ×16 inches, which were sunk by screw jacks. The soil samples were then cut into thin slices and illuminated by a source of ultra violet light in which anthracene is fluorescent, and the exact positions of the fertiliser particles were plotted. It was concluded that the condition of the surface at the time of sowing exerted a great influence on the subsequent distribution. In particular, sowing on rough furrows gave a less even and shallower distribution. Light harrows with tines about 3 inches long carried the fertiliser down to nearly their full depth at one working. A second working produced deeper and more even penetration. Cultivators and deeply penetrating implements appeared to leave the bulk of the manure too close to the surface. It was also remarked that fine-grained manures penetrated more deeply than the coarser ones.

VII.—Root Crop Machinery.

The row-crop or general purpose tractor, developed in the U.S.A. originally for use in maize cultivation, is now being widely adapted there for use with root crops. Corresponding progress in this country has not been rapid, possibly because the machines originally available were not adapted for the usual British row-widths. Preliminary experiments were, however, made at several centres during 1931, and were sufficiently promising to initiate a fuller investigation which is now proceeding. In one

case, where no suitable implements were available for use with the particular tractor employed, experimental cultivating and hoeing attachments were designed and tested. It is stated (Ref. 29) that "the test has shown that it is possible to carry out thorough inter-row cultivation with a full-sized tractor of suitable design," but no details of the work done are available. A general review of the possibilities of developing machinery for beet production is given by Mervine (Ref. 30). The results of an extended trial of cross-blocking receive favourable comment. Alternative suggestions are spaced drilling and transplanting. The writer appears to favour the latter method provided that a suitable transplanting machine can be found. Root topping and lifting machines are also mentioned. With regard to the former, it is stated that, contrary to expectations, preliminary experiments indicate that mechanical topping is not only possible but quite practical. It may be remarked, however, that such trials as have been made in this country suggest, on the contrary, that even when mechanical lifters are used topping is better done by hand.

Davies and Smyth-Homewood (Ref. 31) describe trials of a horse-drawn transplanting machine. The particular machine tried is the latest modification of one which has been seen in this country in its successive stages of development on several occasions during the past four years. It was possible to adjust the machine so as to plant at various distances apart in the rows, the minimum distance being about 14½ inches. In the trial the machine, which carried four boys as feeders, was set to plant spring cabbage at 18 inches apart in 2-foot 6-inch rows. The results showed that the machine would plant satisfactorily at a rate of over 8,000 plants per hour. This may be compared with an average figure of from 600–700 plants per hour for good hand dibbling. The percentage of gaps was about 5½, while some 6 per cent. of the plants were not set with the necessary firmness. The latter figure, it is stated, would have been exceeded in hand dibbling. The actual distance apart of the plants in the rows varied from 11 to 22 inches, the average spacing being 17½ inches. On the whole the performance of the machine was satisfactory, but certain mechanical features are mentioned as requiring strengthening or other alteration. A later model of the machine which can be adjusted down to 6-inch spacing has recently been produced.

VIII.—Electricity in Agriculture.

An article by Brown (Ref. 32) gives a considered account of the possibilities of extending the use of electricity in agriculture. Regarding the electrical tractor as not at present being a practical

proposition, he considers that any successful application of electricity to arable work must be by means of cable sets. But, as he points out, the cable set can perform no useful function in haymaking and harvest and tractors must be retained for this purpose. The use of electricity in arable farming appears, therefore, to be limited to farms large enough to include both types of power unit. With power at 1½d. per kw. the running costs of an electrical ploughing set should compare favourably with those of the petrol or paraffin engined tractor. The use of crude oil tractors may destroy this advantage. The possible use of small sets in intensive market garden work where the greater value of the crop would stand a correspondingly greater expenditure on equipment is also considered. There the running costs have to be compared with those of hand digging or possibly horse cultivation and there appears to be a more promising field for electrical development.

Some mention is also made of electrical soil heating, and references are given to the earlier workers in this field. This subject is attracting a good deal of attention on the Continent and in the U.S.A. A paper by Parks (Ref. 33) points out that with the spread of motor haulage, both on farms and in the city, there is an increasing difficulty in obtaining enough animal manure to fulfil the hot bed requirements of market gardeners. Certain advantages which follow the use of electricity for maintaining the requisite temperature are pointed out, the principal one being the flexibility of control which the method offers. A description of the lay-out for a 12 × 6-foot frame is given, the capital cost of the electrical equipment being estimated at about £1. The consumption of power varies with the external conditions, but it is suggested that from 100 to 250 units will generally maintain a frame of this size through a normal season. Observations which have been made in this country suggest that the above estimates both of cost of equipment and of consumption are much too low. A more reasonable estimate, for Great Britain at any rate, is that given by Nixon (Ref. 34) in a more detailed account of the process based principally on Edholm's work in Sweden. Various examples of American practice are also quoted. These indicate that an average consumption of 1 unit per square yard per day would be required with outside temperatures varying from 32°F. to 70°F. over the season. The cost of electrifying frames including charcoal insulation is stated to be about equal to the cost of the frames themselves. The use of charcoal insulation in providing an adequate supply of carbon dioxide for the plants is also discussed, together with the temperature limitations that are necessary to avoid the production of carbon monoxide. The paper concludes with an account of the crops grown with the aid of electrical heating at

various places, both in American and Swedish districts, one of the latter being well within the Arctic circle. A further article, more readily accessible to readers in this country, is that in which a practical case of the use of electrical heating in cucumber growing is briefly discussed by Mitchell (Ref. 35). An increase of about 60 per cent. in net revenue is claimed, but it is remarked that any general use of the method would spoil the market and so considerably reduce this gain. The successful use over three seasons of electricity for heating a comparatively large outdoor area in Holland is described in *Le Génie Rural* (Ref. 36). In this instance the installation replaced a hot-water system previously used.

The use of electric light on the farm is discussed by Borlase Matthews (Ref. 37) from three different aspects. The first aspect is simply that of ordinary farmyard illumination. Here the installation used on the writer's own farm is described, and it is claimed that the replacement of oil lamps by electricity has resulted in a considerable saving of time in the daily working of a dairy herd. The second aspect is that of increasing the productivity of the farm, principally by stimulating egg production. In a comparison between two batches of hens kept in lighted and unlighted pens respectively, it is claimed that over three winter months an additional profit of about 1*s.* per bird was directly attributable to the use of electricity. The treatment of plant life by intensive illumination is also discussed, an interesting application being in the prevention of a check after transplanting seedlings. Finally, mention is made of the use of ultra violet rays in treating live-stock.

IX.—Drainage.

A memorandum by Blackaby (Ref. 38) gives a very complete review of existing mole drainage practice in England. It is based on the observation of practical mole draining in many parts of the country over the last 6 or 7 years and especially of the work carried out at the numerous demonstrations arranged by the Ministry of Agriculture. The paper includes a great deal of more or less detailed information about the implements used in the various systems of working, particularly about those used for drainage with tractors, whether by direct haulage or by cable winch. Various advantages of the latter method of tractor working are pointed out, amongst which are the greater depth and diameter that can be achieved and the smaller risk of surface damage in certain conditions. In addition, many useful hints as to the working technique of mole drainage are given. A table of the drawbar pulls and horse-powers measured during typical working in the last two seasons brings out one

very interesting point. It is found that the variations in the power required with the same mole plough under different conditions of working are altogether greater than the variations under identical conditions from one plough to another. Since the ploughs differ considerably in various points of detail, it does not appear that research into design is likely to achieve very much in the way of reduced draught. Another point of interest is the suggestion that if a furrow slice is ploughed out and the mole afterwards drawn along the resulting furrow, work may be done at a greater depth without increase in draught. It would appear from this, although the conclusion is not drawn in the paper, that the greater part of the resistance to the passage of the plough is used up in cutting the slit, and that the exact shape of the cartridge is relatively unimportant. Reference is made to mole drains in three parts of the country whose useful life has approached or exceeded 50 years. In one, the drains were drawn by steam tackle, and in another a horse winch was used. In the third, a team of 10 horses provided the necessary power for direct haulage. One further observation may be mentioned. In a certain instance drains drawn in 1922 at a depth of 22 inches were found in 1928 to have flattened out considerably and to be at a depth of only 16 inches. It would be interesting to know whether this phenomenon is at all general and also to know how the process finally ends. The paper concludes with a very complete list of references to other works on the subject, including several of recent foreign orgin. With regard to the danger of the slits of mole drains opening in dry weather, another writer (Ref. 39) mentions a recent case in which opening to as much as 3 inches occurred. It was concluded that none of the methods ordinarily suggested for obviating this contraction would, in that case, have succeeded, and that therefore in certain soils it is vitally important to draw the drains at a time when it is likely that wet weather will follow.

Reference was made in the last volume of *Agricultural Research* (p. 85) to what is now known as the Poppelsdorf system of mole-tile drainage. An American article by Wallem (Ref. 40) gives a concise account of the method in a form more readily adapted to English readers. The method consists of stringing the tiles on a rope which is attached to the back of the cartridge and which is drawn behind it into the mole. The tiles are centred on the rope by a series of egg-shaped spacers which ensure substantially perfect continuity from tile to tile. Another ingenious feature is the hitch between the tile rope and the cartridge, which releases itself automatically at the end of the drain, allowing the rope and spacers to be drawn out from the starting point. The tile-laden ropes are now made up in

lengths of about 100 feet and continuous drains up to 400 feet long have been drawn quite successfully. A paper by Rickert (Ref. 41) describes a series of German experiments on mole drainage during the latter part of which an extended trial of the Poppelsdorf system was made. In moist soil a somewhat unexpected difficulty was encountered in that the drains contracted so rapidly after the passage of the cartridge that it was impossible to draw normal-sized tiles into the mole. Rapid shrinkage of this kind does not appear to have been reported by any observers in England. It is, however, possible that the subsoil in this case was not so stiff as is generally considered necessary for successful mole drainage by ordinary methods. The difficulty was, of course, overcome by using a cartridge whose diameter was considerably greater than that of the tiles. The paper estimates the costs of drainage by the new system as being about half as much again as those of ordinary mole drains. This would, of course, be much less than the cost of hand-laid tiles, and in view of the claims which are made for the efficiency of mole-tile drains drawn in this way, the Poppelsdorf system appears to be worthy of further attention.

Reference was also made in the last volume to the fact that mole drainage on a large scale was to be attempted in connection with the Zuyder Zee Reclamation scheme. This work has since been started, and is described by Von Köller (Ref. 42). The ingenious methods of producing what are, in effect, reinforced mole drains would, however, appear to be too complicated for use in agricultural drainage unless on a very large scale.

X.—Research on Cultivation Problems.

In the contribution previously referred to, Keen (Ref. 22) discusses some of the problems which underlie the true application of mechanical power to cultivation as distinct from the mere replacement of the horse by the tractor. He points out that as yet it cannot be predicted what will be the effect on the ultimate tilth either of a change in the shape of the tool or of an increase in the speed of working. As the Rothamsted experiments show, weather conditions in any case exert such a powerful influence that it would not be far wrong to say that in a favourable season any tool will do. Other experiments show that on medium heavy soils it is unnecessary to adhere too rigidly to the traditional seasons at which the various operations are carried out. Thus different implements can be hitched together so as to combine several operations in one without detriment to yield. Many of our more advanced farmers, especially those to whom reference has been made in this article,

have, of course, been working in this way for several seasons past. Without being in a position to draw any definite conclusions as to the effect on yield, they have satisfied themselves that on the grounds of economy of power alone their procedure is justified. The most interesting part of this discussion is that which deals with rotary cultivation. The failure of this method to fulfil the expectations of its advocates is apparently due to the fact that it does not really produce a finer tilth but only a looser one. The advantage which the rotary tilled seed-bed gives in the earlier stages of the growth of the plant is, for this reason, entirely lost before harvest, while usually a heavier growth of weeds adds to the final failure. There is, however, a possibility that a rotary cultivator with a ridging attachment behind may solve the difficulty.

The work on soil consolidation which is being carried out at Wye College has a bearing on some of the problems mentioned in the previous paragraph. The work as a whole has recently been summarised by Davies (Ref. 43) who also gives elsewhere (Ref. 44) some of the results of the 1929–30 experiments. In the first set of experiments the yields on plots prepared by hand digging and forking, both with and without treading, so as to give varying degrees of tilth and consolidation, were compared. No significant differences in the yield of either grain or straw were recorded. In a second set of experiments, comparisons were made between four seed beds prepared respectively with two forms of mould-board plough, a pulverator and a rototiller. In this case appreciably better results were given by the mouldboard ploughs, while of the two types of plough used that with a general purpose breast was superior to the digger. The experiments were repeated in 1930–31 (Ref. 45) when substantially the same results were obtained. It was concluded that on that particular soil (Wye Loam) and during those particular seasons, the finer tilths produced by both the rototiller and the pulverator were unsuitable for cereals. In a further paper (Ref. 46) the same writer describes an instrument designed to measure the soil consolidation in work of this kind. This instrument, which he has named the Soil Compactometer, is an improved model of one previously described by him. The Compactometer has been used to measure the resistance to penetration into certain kinds of soil of a number of probes of different external form. The results show very large variations in the resistances offered by the different shapes and lead the writer to suggest that "the shapes of all cutting edges and piercing points can be designed in a way conducive to the least expenditure of energy for the work to be done."

A further experiment by the same worker (Ref. 47) may be briefly referred to. It was noticed in May that, in a field of

barley which had been worked with a tractor, there appeared to be certain parallel lines of stronger growth. It was established that these lines corresponded with the wheel tracks made by the tractor during disc harrowing two days before drilling. Measurements of the numbers of plants, tillers, and ears, and of the ultimate yields from a number of random foot lengths taken in and out of the wheeltracks were made. Although the numbers of plants per foot length were the same in both cases, the numbers of tillers and ears were appreciably greater in the wheel tracks and a considerably larger yield resulted. Similar lines across the field due to the tractor wheels during drilling were also noticed, but in this case the measurements failed to disclose any significant difference in yield. Records of the rainfall and state of the soil have been kept and are to be studied in relation to the above results. Formal experiments are now being carried out in which the action of the tractor wheel is simulated by a specially designed roller.

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PESTS AND PARASITES.

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SINCE the subject of Pests and Parasites has not previously been dealt with in this publication, a few introductory notes seem necessary.

In the first place, it may be recalled that until recently agricultural entomology has been relatively neglected, and while the Royal Agricultural Society has, perhaps longer than any other organisation, recognised the importance of the subject, the amount of investigation or research which has been devoted to it in Great Britain has been quite inadequate. Since the war, conditions in this respect have to some extent changed, and those sections of the public most directly concerned have realised more definitely than ever before that crops and animals attacked by pests and parasites are not in modern circumstances a paying proposition. As a result, work in many directions is now in hand, but in the following account of it references are only made to those lines which have given or are giving results that appear likely to be of commercial value to the practical man, and no attempt is made to describe the research which is being carried out as a whole.

Next, as to the range of subjects covered, it may be true that agriculture and horticulture are distinct branches of the industry, but it is equally true that the agriculturist and the horticulturist are often one and the same man. The farmer in Kent or the West of England is frequently interested in fruit,

the bulb grower of Lincolnshire in potatoes, and the Worcestershire farmer in hops or market garden produce, and in consequence it does not seem useful or even possible in such an article as this to limit discussion to those subjects which are agricultural in a narrow sense ; only those matters are ruled out, therefore, which are solely of interest to such highly specialised forms of cultivation, as the tomato industry or mushroom growing. This leads to one further point—since the war, corn growing and most forms of mixed arable farming have experienced the effects of the world depression more than those branches of the industry in which the cultivation is more intensive or is of a more specialised character. The interest in crops of the former type has therefore tended to decrease, and there has been a simultaneous increase in attention to those of the latter type which have met with a relatively better market. This transfer of interest on the part of the grower has naturally been reflected in research and, in consequence, recent investigation has been concentrated rather upon the troubles met with in the cultivation of such crops as fruit or sugar beet than upon those of wheat or oats. In the long run, of course, the question is largely one of economics, since the more money that can be spent on the control of a pest, the greater are the chances of success, and the entomologist is presented with an almost hopeless task when he is asked to control a serious pest with practically no expenditure.

Finally, it may be noted that, while this publication refers nominally to the year 1931, the results of research do not appear annually in regular " crops " and, in consequence, it seems necessary to review to some extent the work of the past three or four years and not to limit these notes to matter actually published last year.

I.—General.

The work described in the following sections is classified according to the crops that are concerned, but it may be of interest, in the first place, to indicate the chief lines of entomological work that have recently been attracting most attention. Of these the subject that has perhaps received the greatest advertisement is the endeavour to prevent damage to crops by encouraging or introducing " beneficial " insects that have the useful habit of destroying pests. The possibility of dealing with insect enemies in so easy and cheap a manner, and the success that has been achieved in a certain number of cases, have naturally attracted the journalist, with the result that highly coloured and often unduly optimistic articles appear in the press. The practical man who reads these accounts in the

papers may easily be deceived into believing that all his difficulties from pests can be solved by the discovery of beneficial insects that can be reared in vast numbers in a so-called "parasite zoo" for use when required. As farming opinion can influence very greatly the directions in which the funds available for research should be spent, it is worth pointing out that the men who have done the best work in controlling pests by means of beneficial insects have never made exaggerated claims for the method. Dr. Thompson, for instance, who is Director of the Parasite Station of the Imperial Institute of Entomology at Farnham Royal, and who has spent many years in this type of work, has described the conditions under which success is likely (Ref. 1) and while it is clear that Great Britain is not an area in which to expect spectacular results, the practical man may rest assured that such possibilities as do exist are not being overlooked. It is, however, quite evident that for the destruction of the majority of our more serious pests, chemical or cultural measures must be used, and so far as Great Britain is concerned research should chiefly be in these directions.

A second line which is being actively pursued is the endeavour to discover new insecticides or to find new uses for those already known. This work is having a very practical outcome, for instance in the greatly increased use of the toxic properties of Derris root (*Derris* being a genus of tropical plants which is found growing wild, and is also cultivated in plantations in the East). Similarly, pyrethrum insecticides (obtained from the flowers of special kinds of "Pyrethrum") which had fallen into disrepute owing, probably, to the irregularity in quality of the commercial supplies of dried pyrethrum flowers, are now proving of considerable practical use where an absolutely non-poisonous insecticide is wanted. In each case the great need has been for methods of standardising the insecticides, and work at Rothamsted (Ref. 2) has gone far to show how this may be done. Obviously from the practical point of view, it is essential that the purchaser should buy insecticides of known strength, and the work on standardising such insecticides as Derris and Pyrethrum is, therefore, of first importance.

Another group of insecticides which has been the subject of much investigation is that comprising the various winter washes. The introduction of tar distillate washes shortly after the war, and their remarkable success against certain pests, led to a desire on the part of growers, and attempts by investigators, to increase the usefulness of these washes by their application to a greater number of pests and notably Capsid Bugs. Under experimental conditions a large measure

of success was achieved, but commercial exploitation of the work—for which the investigators themselves were not responsible—perhaps followed too quickly, and it has not proved possible to reproduce the experimental successes consistently or on a universal scale. While European investigators were dealing with tar distillates, their colleagues on the American continent were devoting their attention to the use of heavy mineral oils, and they also obtained such considerable success that oil washes of this type were tested in England, and it was rather remarkable to find that some of the pests against which tar distillates were ineffective were destroyed by mineral oils, and *vice versa*. It would seem, therefore, that a wash combining both tar distillates and mineral oils may prove the final solution.

The question of insecticides leads to one further line of work which has given and is giving results of practical importance, and this is the use of baits. Where the pest can be persuaded to eat some cheap and readily distributed bait, the latter can be rendered poisonous, and the destruction of the pest effected. Moist bran has for long been known to be attractive to cutworms, and rendered poisonous with Paris green, it has been used in this country for some years. Subsequently it has been found to be effective for leather jackets and slugs, and other baits are being found equally successful for different pests abroad and may find their use in England.

Finally, reference may be made to a subject that is receiving much attention in most parts of the world, and would justify more attention in England. The efficiency and the cost of applying insecticides are determined not only by the poisonousness of the chemicals used and their price, but equally by the methods by which they are applied. Insecticides are most often used after mixing or solution in water, which itself is not toxic to insects. It would therefore seem at first sight that the cost of carrying and spraying the water is pure waste and should be dispensed with. To secure this object, therefore, "dusting" was introduced as an alternative to spraying, and it has achieved a certain measure of success, largely owing to the rapidity with which a dust can be applied as compared with a wet spray. For farm use the possibilities of dusting have not yet been sufficiently explored, but, at the time of writing, opinion in America, where dusts have been most extensively tried, seems to be less favourable to dusts for treating fruit than it was a year or two ago. As an alternative, endeavours are now being made, both at home and overseas, to increase the efficiency of wet sprays and lessen their cost by improving the spraying machinery and the technique of spraying, and it would seem that in this direction there is most scope for

success. The use of aeroplanes for applying insecticides, which has also had a good deal of newspaper publicity has so far proved very limited. It seems only suitable where large areas of a single crop are grown, and so is less likely to be useful in England than elsewhere.

II.—Cereal Crops.

As was pointed out in the introduction, the depressed condition of corn-growing in England has resulted in investigators turning their attention to those crops which have been giving better financial returns, and, in consequence, there is relatively little to report in this subsection. The following notes may, however, be of some interest.

Frit Fly. (*Oscinella frit Linn*).

There are three generations of the fly during the year, two of which cause damage to spring oats. The harm which is most obvious is that done by the Frit maggots to the crop at the end of May and in June, and it is now generally realised that at present the only method of preventing the loss is by early sowing.* It is less generally known that the next brood of the fly, of which the maggots feed within the oat kernal, also does a great deal of harm to the crop, so that it is well to realise that early sowing is effective in this case also. It has been shown at Manchester (Ref. 4) that oats sown on 15th March suffered a loss of 19.9 per cent. of grain, but when sown on 15th April as much as 54.6 per cent.

Leather Jackets. (*Tipulidae*).

The value of the bran and Paris green bait for Leather Jackets (Crane Fly grubs) is now fairly generally known, but relatively little has been published about it and there may still be farmers who have had no practical experience of its use. In Shropshire, an 80 per cent. control was obtained by the use of poisoned bran at the rate of 25 lb. per acre (Ref. 5), and other successes have been recorded in Wales (Ref. 6). There is some difference of opinion as to the best formula for the bait and the exact quantity to apply, and it is probable that a fair amount of latitude in these respects is permissible without interfering with the result. A mixture of bran, 25 lbs. and Paris green 1 lb., has been found satisfactory at the Seale Hayne College, in Devon (Ref. 7). The bait should first be rendered moist,

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*The breeding of oat varieties resistant to Frit is proceeding at Oxford (Ref. 8) and some initial success has been obtained, but the work has not yet reached the commercial stage.

but not so wet as to allow the particles of bran to stick together. The possibility of damage to birds and game is sometimes raised, but it would seem that it is negligible provided the bait is used properly, i.e., is distributed uniformly and thinly, special care being taken not to spread the bait in lumps.

Wheat Bulb Fly. (*Hyelemyia coarctata Fln.*)

In most wheat growing districts the maggots of this fly cause the wheat to go off in spring, and in some years the losses are so heavy as to necessitate resowing with some spring crop. The fly lays its eggs towards the end of the previous summer, and it has been known for some years that wheat is most likely to suffer when sown on land which was then in bare fallow. It seems, therefore, that the fly prefers to lay her eggs on land which is bare, or relatively bare, of crops. This, however, does not altogether explain the attacks which in certain seasons follow potatoes, and sometimes other crops, which have covered the soil almost entirely when the fly is egg-laying. Further light is thrown on the problem by some observations made in Germany where two workers have shown that the largest number of eggs are laid in soil which is dry on the surface, and the least in wet (Ref. 3). It would therefore seem that the preference of the fly for bare fallows is because the soil in such fields is often dry ; similarly with potatoes, the soil has been well worked and the top is usually loose and dry, and is thus often suitable for egg-laying. From the wider point of view, it may also be deduced that where there is a choice of fields for wheat, preference should be given to those which were not dry and loose on the surface in July and early August as is often the case with roots and potatoes.

III.—Potatoes.

While potatoes suffer seriously from various fungus diseases, they are not, in Great Britain, very subject to damage by insects.

Potato Sickness.

Of increasing importance is a trouble known as "potato sickness," primarily due to the attacks of the Potato Eelworm, a worm which is indistinguishable from the notorious Beet Eelworm of the Continent, one of the most important pests of sugar beet. From the recent work on the Potato Eelworm (*Heterodera Schactü Schmúlt*) in England, the most important practical deduction is that the numbers of the worm in the soil can only be kept in check by rotation of crops, no chemical disinfectant having so far proved of real use.

On land which shows no evidence of potato sickness, potatoes once in three years is probably quite as often as safe, while where the land is becoming sick a five years' interval between potato crops, or even more, may be necessary. It is possible that in potato sickness some soil trouble, not yet understood, may contribute to the damage by hampering the root growth of the potato in the early stages, and this may explain the good results which have sometimes followed dressings of crude naphthalene, since such dressings do not apparently affect the eelworms. Similarly, heavy dressings of dung and applications of calcium cyanamide have temporarily allowed the harvesting of good crops on sick land, doubtless by assisting the potato plant, and not by checking the eelworm. It is doubtful, however, whether in the long run it is good policy to adopt such expedients in order to grow potatoes on sick land, as it seems likely that the eelworm population will continue to increase and the sickness, in the end, will be all the worse. In some districts, growing mustard is reported to be a cure, but the field experiments which have so far been carried out do not support this idea.

As the investigations on potato sickness have been largely of a co-operative nature, references have not been made above to the precise stations at which the various experiments have been made, and it is sufficient to regard that work has been in progress at the Institute of Agricultural Parasitology, at the Ministry's Laboratory at Harpenden, at Kirton, Leeds, Manchester, and the West of Scotland Agricultural College (Ref. 11).

Virus Diseases.

Of greatest importance in this connexion is the fact that Leaf Roll, Mosaic, and other virus diseases are carried from diseased to healthy plants by green fly. The part played by green fly in the transmission of these diseases has been shown at Cambridge (Ref. 9), and on a commercial scale it has been demonstrated that in a district in North Wales relatively free from fly, potatoes can be grown continuously without degeneration owing to virus. It would seem that the virtue of seed from the North of Scotland is largely due to the fact that green fly is scarce there, and that a similar absence of greenfly is to be expected in hilly districts in England and in coastal regions where there is often a strong wind. The practical application is that farmers with land in such areas might be able to build up a useful trade in seed potatoes, provided that they have the assistance of someone trained in recognising virus diseases, as is being attempted under a scheme supervised by the University College of North Wales, Bangor (Ref. 10). Whether it would be possible, and if possible worth

while, to keep potato crops in ordinary districts free from fly by dusting or spraying, and so check the spread of virus diseases, has not yet been proved.

Colorado Beetle. (*Leptinotarsa decemlineata Say.*)

Although this pest is not yet in England, the menace is becoming definitely greater. During 1931, the beetle reached a point within 40 miles or so of the north coast of France, and there was an extensive spread in the valley of the Loire. The French have found that spraying is effective in preventing the destruction of their potato crops, but it is clearly not succeeding in eradicating the insect from France. A further extension northward must therefore be expected, and when the beetle reaches that part of the coast of France nearest to England, no measures that the Government can take will prevent periodical invasions of England. Even then it should be possible to keep England normally free from the pest, provided that the outbreaks are detected and reported to the Ministry of Agriculture in time, and this is the crux of the matter. The Colorado Beetle was in France for two or more years before it was recognised, and it was then too late to tackle it effectively. Government inspection of every potato field and allotment in England is obviously impossible, but it is not impossible for the grower himself to watch his own crop, and the prevention of the establishment of this troublesome pest of the potato is thus primarily in the hands of the potato growers themselves.

IV.—Roots and Farm Vegetables.

In comparison with cereal crops, roots and farm vegetables have received a relatively large share of the attention of the investigator, a fact partly due to the importance of sugar beet in European farming. Fortunately, many of the more serious sugar beet pests of the Continent do not occur in England or are not yet sufficiently numerous to do harm, and much of the Continental work is thus not of immediate importance to the practical man : if sugar beet growing persists in Great Britain, an increase in the kinds of pests which attack it may be expected, and European experience will then prove very valuable.

Cabbage Root Fly. (*Chortophila Grassicae Bché.*)

Cabbages, cauliflower and broccoli, whether grown on a field or garden scale are almost everywhere subject to extensive losses from the maggots of the fly, which eat away the roots

of the plants shortly after they have been set out. Several workers in England have been dealing with this pest, and they find that the losses may be largely prevented either by dressing the soil round plants with naphthalene, about 2 ozs. per sq. yd. (Refs. 18 and 22) or by watering them with a very weak solution of corrosive sublimate (Ref. 23). The naphthalene treatment is perhaps slightly less effective, but it requires no water and is cheaper. On the other hand, it appears that corrosive sublimate also assists in protecting the plants from the attacks of slugs and club root, and it has the advantage on soils affected by them. It may be mentioned that the corrosive sublimate treatment is the standard commercial method adopted by the Canadian and American growers, but there are objections to handling such a poisonous substance (it is *very* poisonous), and where the naphthalene treatment succeeds, it should perhaps be preferred. It is also worth noting that in Russia both the corrosive sublimate and the naphthalene treatments are found too expensive, and a worker there has discovered (Ref. 24) that watering the plants with a very weak solution of tar distillate (2 or 3 pints of tar distillate to 10 gallons of water), is quite effective. But damage to the plants might be expected even from so weak a mixture and it would be wise to test the treatment first on a small scale.

Onion Fly. (Hylemyia antiqua Meig.)

The maggots of this pest attack the onion at the same time as those of the previous pest attack cabbages, etc., and while the naphthalene treatment mentioned in the last section may also be tried, it is worth recording that, in Canada, good results have been obtained (Ref. 25) by spraying or watering the plants and soil around them with a lubricating oil emulsion made as follows :—1 gallon of lubricating oil (as used in motor-car engines) is mixed with 1 gallon of Bordeaux Mixture, freshly made according to the usual formula (4 lb. copper sulphate, 4 lb. quick lime, 40 gallons water). Thoroughly stirring the Bordeaux Mixture emulsifies the oil to form a stock solution. Two gallons of this stock solution are mixed with 40 gallons of water, and 4 applications are given at weekly intervals, beginning early in May.

Capsid on Sugar Beet. (Lygus pabulinus Linn.)

The Common Green Capsid was found doing serious harm to a crop of sugar beet in the west, and it may therefore be noted that the Long Ashton entomologists got excellent results by dry spraying with a nicotine dust (Ref. 17).

Carrot Aphis.

In certain seasons carrots suffer severely from "green fly" and it is therefore worth recording that at Harper Adams spraying with nicotine and soap was completely effective in saving the crop (Ref. 20).

Carrot Fly. (*Anuraphis dauci Fab.*)

This pest, which is very troublesome to carrot growers, has been under investigation at Cambridge, The Midland Agricultural College, and in Scotland and elsewhere. Dressings of naphthalene up to 4 cwt. per acre have given some results against the first brood of the fly, but owing to the need for frequent applications the difficulty of dealing with the second brood remains, and the treatment must still be regarded as experimental on a farm scale in England (Ref. 18). In Scotland, on a garden scale, it has been found that applications of naphthalene, 1 oz. to 2 sq. yards weekly, from the germination of the carrots to the end of June, and three subsequent applications at intervals of ten days was completely effective, but for farm use this programme would seem too expensive (Ref. 19).

Diamond Back Moth. (*Plutella Maculipennis Curtis.*)

In certain years the minute caterpillars of this moth do a great deal of damage to turnips, swedes, kale, and such vegetables as cabbage and Brussels sprouts, generally during the latter half of July or early August. The old remedies, such as brushing root crops with bushes tied behind horse harrows, are relatively ineffective and clumsy, and it is therefore of interest that workers in New South Wales find that dusting the crops with either lead arsenate or nicotine is quite successful (Ref. 21). On the other hand, spraying with lead arsenate is of no use unless a "spreader" such as calcium caseinate be used. Evidently, widespread losses such as occurred in 1914, for instance, are preventible and need not occur again, but it may be suggested that a close watch on the crops is desirable so as to apply the remedy before too much damage has been done.

Mangold Fly. (*Pegomyia hyoscyami Panz.*)

The maggots of this pest burrow in the leaves of sugar beet and mangolds, and in certain years do much damage by checking, or even killing, the plants when they are young. In England, rolling at this period, when this operation is possible, has given very fair results, but it is not practicable in all soils and all weathers, and chemical treatments which are most in favour with Continental beet growers are therefore of

interest. That most recommended in Belgium and Hollan is to spray the crop when the first brood of the flies emerge with a poisoned bait made of sugar and sodium fluosilicat (Ref. 12). The work has to be done at exactly the right time which in Belgium is discovered by placing maggots of the fl obtained in the previous season in cages in the fields so as t detect the date of emergence of the flies—much in the sam way that the Americans find out when to spray for Codlin Moth. The treatment thus renders desirable the co-operatio of an entomologist, but any farmer in England who wishes t try it will have no difficulty in obtaining the help of an Advisor Entomologist (Form A 705/TG of the Ministry of Agricultur gives a list of such entomologists). Another chemical treat ment which Theobald tested. in a preliminary manner year ago, is to spray the crop when the tunnels of the maggots ca first be seen, with a nicotine insecticide. This method ha again been tested in Italy where it is found that a solutio containing 0.25 per cent. nicotine sulphate is effective, tw applications being given, the first when the first signs o burrowing in the leaves is detected, and the second ten day later (Ref. 13).

Pigmy Mangold Beetle. (*Atomaria linearis Steph.*)

This minute beetle, which has been known for many year as a relatively unimportant pest of mangolds, has proved ver injurious to sugar beet since the introduction of the crop int Great Britain. The insects eat the roots of the plants jus below ground in the seeding stage, or after the "rough" lea has been produced ; the part of the root attacked withers and a constriction is caused, with the ultimate result that the tap root is severed from the leaves and crown. (Somewhat similar damage is done by Springtails, but it may be distinguished by the fact that it occurs at, or just above, ground level and is usually of less importance).

Although little has yet been published on means of dealing with the Mangold Beetle, the problem has been receiving attention in several quarters, and as a result the first point which would seem to stand out is that serious attacks occur when sugar beet or mangolds are grown for two or more years in succession on the same land. It was found, for instance, at Rothamsted that by continuous cropping with mangolds or beet the numbers of beetles in the soil were greatly increased (Ref. 14), and for the same reason this procedure is strongly disapproved in advice given by the South-Eastern Agricultural College (Ref. 15) and elsewhere. There can be no doubt that growing beet after beet is bad practice, as it is almost certain ultimately to result in losses by Mangold Beetle or some

other pest, and the field may become incapable of growing beet for a long period.

A second method of dealing with Mangold Beetle which has given some success at Kirton and the Harper Adams Agricultural College is to steep the seed before sowing for twenty minutes in a mixture consisting of carbolic acid 1lb., magnesium sulphate 5 lb., water 10 gallons (Ref. 16). It is not very clear how this treatment works. The carbolic acid presumably has a temporary deterrent effect on the beetles, but it may be that the main effect of the mixture is to increase the rapidity of germination, so enabling the plants to pass more quickly through the stage when they are more susceptible to injury.

Dusting, etc.

Although published work is still rather inconclusive, it would seem to be a growing tendency to use nicotine and other dusts for the control of vegetable pests—*e.g.*, flea beetles ("Turnip fly"). The matter is only mentioned here as it would seem to render worth while the possession by all large scale vegetable growers of an efficient dusting machine.

Poison Bait.

The use of the Paris green and bran bait has been referred to previously, but it is worth noting again here that it has proved very effective in certain cases in preventing losses by slugs to newly set out Brussels sprouts, cabbage, etc.

V.—Fruit.

As has already been mentioned, one of the most striking features in the investigation of pests and parasites in 1931 and in the previous year or two, is the attention that has been given to fruit crops.

Many of the investigations in progress, although they have already given results of practical value, are still incomplete in that a search is continuing for better or cheaper methods. Therefore it is often better to give the reader an idea of the trend of the work rather than to present cut and dried conclusions which may have been the last word in 1931, but may have already been modified at the time when this account is read.

Winter Washes.

Before dealing with the various pests, it is necessary to make some further reference to winter washes and their use

in fruit plantations—a subject of the greatest practical importance, but one that more than any other, perhaps, is in the state of flux noted in the previous paragraph.

Some five years ago it appeared that the use of tar distillates had become more or less standardised as a control for aphides and apple suckers, and the different commercial brands gave, in practice, very similar results, The insistent demand for a winter wash which would control capsids, and which incidentally would be more destructive to Winter Moth eggs, led to work at Long Ashton on the composition of tar distillate washes, and to work at that station, and Cambridge (Ref. 26), Wye, and elsewhere, on mineral oils. Under experimental conditions so successful were the results obtained by Long Ashton workers (Ref. 27) that an immediate demand arose for the supply of the so-called "Long Ashton" washes on a commercial scale, and makers were forced to meet the demand perhaps before the important stages between experimental success and commercial exploitation had been fully bridged. Either on this account, or because weather conditions in recent years have not been favourable to tar distillate treatments, the results obtained in practice have been very variable, notable successes being mingled with failures to control Capsids, and with cases of severe damage to buds.

While search for an improved tar distillate wash was in progress, success had also been obtained against Capsid eggs by means of mineral oils, which, however, proved useless against aphides. Workers therefore turned their attention to methods of combining the virtues of mineral and tar distillate oils ; and, at least where Capsids are abundant, the tendency is now to use either a mixture of mineral and tar oil, or to make two separate applications—the first a relatively weak mixture of tar distillate (5 per cent or 7 per cent.) after mid-winter, to control aphides, and the second a mineral oil at the extreme close of winter, as late as is deemed safe, to destroy Capsids. However, no finality has yet been reached, and more work on the subject is certainly needed, not only of the practical field trial type but also in the laboratory.

Finally, it may be noted that the variability in the results obtained from these winter washes led to the desire on the part of some growers to make their own tar or mineral oil washes without using any ingredient of a proprietary character, and reference may be made to a note in the Wye Journal on oleic acid as an emulsifier, which would seem to answer the purpose satisfactorily (Ref. 28). This, however, must not be read as suggesting that tar distillate washes can profitably be made at home.

Apple Sawfly. (*Hoplocampa testudinea Htg.*)

Spraying with nicotine and soap, first found successful by Petherbridge and Tunnington, still appears to be the best method of controlling this very serious pest. It is advised that the spray should be applied 7 days after petal fall (Ref. 28a).

Capsid Bugs. (*Plesiocons nigicollis Fall.*)

The attempts made to control these pests by means of winter washes have been dealt with above, and it needs only be said here that by the use of mineral oils or special winter washes the growers appear to be definitely getting the best of the battle. Spraying with nicotine is still necessary where the pests are very numerous, and greasebanding is found in Kent to be worth while to prevent those bugs which have been knocked off the trees, but not killed by the spraying, from climbing back (Ref. 29).

Nicotine dust have been found useful to control the Common Green Capsid ("*Lygus*") on bush fruit (Ref. 29).

Clay-Coloured Weevil. (*Otiorrhynchus singularis Linn.*)

Farm orchards and others planted with unsatisfactory varieties are often top-grafted, when the young scions may suffer seriously when breaking into leaf, or earlier, from the attacks of this and other weevils. East Malling finds that the damage in nursery stock may be prevented by painting the grafts with lead arsenate thinned to a paste with water, and the same treatment should be effective on larger trees top-grafted. (Ref. 31). As the Clay-Coloured Weevil cannot fly, grease-banding is also effective, but this does not apply to all weevils that attack grafts.

Codling Moth. (*Cydia pomonella Linn.*)

The extensive use of tar distillate winter washes has led to a decrease in the use of insecticidal sprays in spring, and possibly on this account there has been a definite increase in the losses caused by Codling Moth. East Malling draws attention to this fact, and advises a greater use of lead arsenate applied as soon as the apple blossom has fallen (Ref. 30).

Pear Midge. (*Confarinia pyrivora Riley.*)

Both the East Malling and Long Ashton Fruit Stations have had this serious pear pest under investigation. At East Malling it was found that the cultivation of the soil under the trees with a horse-drawn "Planet Junior" once a week between June 10th and July 5th gave good results (Ref. 32). The

Long Ashton workers found that $\frac{1}{2}$ oz. of calcium cyanide per square yard, worked into the soil in June, was effective in lighter soils ; and that nicotine and soap sprayed into the open pear blossom resulted in a marked reduction in the percentage of the fruit attacked (Ref. 33).

Pith Moth. (*Blastodacna atra Haw.*)

For many years it has been suggested that spraying in late summer might control this insect by killing the larvae before they have burrowed into the young shoots. A study of the habits of the pest, made at Manchester, shows that this treatment is very unlikely to be effective and that it would almost certainly prove a waste of money (Ref. 34).

Raspberry Beetle. (*Byturus tomentosus Fab.*)

The demand for loganberries and raspberries for canning has rendered this insect of great importance, since maggotty or damaged fruit is useless. The attentions of investigators have therefore been concentrated on the pest, and their work is leading to practical conclusions. Long Ashton has obtained promising results by spraying three times with a pyrethrum insecticide, infestation being reduced from over 60 per cent. to under 20 per cent. (Ref. 35). East Malling also had some success with a spray of the same type, but even more by means of two sprayings with a wash containing " derris " and soap, which is considerably cheaper than pyrethrum washes (Ref. 36). The work is progressing very favourably, and by the time this note is in print not only will a further season's experimental results be available but also those of a number of growers who have taken the matter up. It is not advisable therefore to discuss the details of the work here, and readers who are interested will have no difficulty in getting the latest information either from the Horticultural Research Stations, or through the fruit-growing press.

Red Spiders.

The control of the Fruit Tree Red Spider, which has become such a serious pest of top fruit since the introduction of tar distillate washes (which are not effective against it) is now beyond the experimental stage, and for varieties of fruit which are not sulphur-shy, spraying with lime-sulphur is a remedy. A mineral oil wash applied in the " delayed dormant " season is an alternative when sulphur cannot safely be used ; and the extent of the control obtained in this way is shown in an experiment in Ireland in which 90 per cent. of the mites were found to have been destroyed by the wash (Ref. 37).

Strawberry Mite or Strawberry Tarsonemus. (*Tarsonemus fragariae Zimm.*)

Few horticultural problems have proved so troublesome or difficult of solution as the unsatisfactory condition of the strawberries since the war. It has been attributed by various workers to faulty cultivation, to eelworms, and to aphides (green fly), while within the past year or two a further possible cause has been discovered in a minute mite which appears to be widely distributed, and has been shown experimentally to be capable of causing very serious damage to strawberry plants (Ref. 38). The extent to which this newly discovered pest is actually contributing to the difficulties of strawberry growing is still uncertain, but in view of its capabilities for mischief, it is clearly desirable that new plantations should be planted-up with runners as free from the mite as possible. Work carried out at Seale Hayne and Reading suggests that dipping the plants in hot water (110° Fahr.) for 20 minutes is likely to prove successful if precautions are adopted to prevent the wet plants from "heating" after they have been dipped.

The position reached in 1931 is summarised in lectures given by various investigators at Reading, and those interested in strawberry growing should refer to the Bulletin XLI, in which the lectures were published (Ref. 39). At the same time, it must be pointed out that more will be known as to the hot water treatment of strawberries by the end of 1932, and this note is chiefly designed to draw attention to the matter.

Strawberry Weevil. (*Anthonomus rubi Herbrt.*)

This beetle, which in certain districts causes much loss by destroying a high percentage of the blossoms, has been under investigation at Botley (in Hants.), at Wye, and also in Sweden. It is found that the weevils spend the winter round the outsides of the fields, largely in hedge and ditch bottoms, and that burning over the plants after cropping is of no avail (Ref. 40). In Sweden hopeful results have been obtained by dusting the plants with an arsenical dust in May, prior to the setting of the fruit (Ref. 41). Apparently there was no objectionable arsenical residue left by the time the fruit was picked. This treatment is being tested at Botley in 1932.

Winter Moths. (*Cheimatobia brumata Linn*, etc.)

Although the methods of controlling these pests have been known for so long, there are still far too many orchards which are allowed to suffer year after year. Work carried out at Wye and Reading suggests that this may be partly due to reliance being placed on tar distillate washes, which do not give sufficient control (Ref. 42). Similarly, it is found that under

practical conditions, greasebanding, although useful, is not usually wholly effective. The use of lead arsenate early in the season (in pre-blossom sprays for apples) seems imperative if a satisfactory control is to be obtained.

Woolly Aphis. (*Eriosoma lanigerum Hausm.*)

Woolly Aphis is often troublesome on the cut surface of the branches of top-grafted trees. It is found in America that a mixture of greasebanding material and nicotine painted on gives protection for a long period (Ref. 43).

VI.—Miscellaneous.

Foxtail Midge. (*Dasyncura alopecuri Rent.*, 4 other species.)

Attempts at growing Meadow Foxtail for seed often end in failure owing to damage caused by the maggots of this pest, which feed in the flower spike (or " ear "). It has been shown at Rothamsted that the loss may be very greatly reduced by grazing or rough cutting the grass in the spring, so as to delay seeding time (Ref. 44). For instance, when the grass was kept cut up to May 13th and then allowed to run to seed, the loss was only 11 per cent, whereas with grass allowed to run to seed without any previous cutting, the loss was 80 per cent.

Hop Flea Beetle. (*Psylliodes attenuatus koch.*)

It is found at East Malling that neither spraying nor dusting is very effective against Hop Flea Beetles, but that jarring the bine over boards covered with greasebanding material is both practicable and successful (Ref. 46).

Mustard Beetle. (*Phaedon cochleariae Fab.*)

Certain European investigators have shown that a dust containing one part of calcium arsenate to three parts of lime (applied as a dust) is very successful against this pest (Ref. 45).

Narcissus Flies. (*Merodon equestris Fab.*)

As daffodils are now almost a farm crop in certain districts, it is worth drawing attention to the fact that a poison bait spray is giving hopeful results. The spray consists of sodium arsenite 4 ozs., crude glycerine 1 lb., sugar (white) 2 lb., water 4 gallons. An application of *not more than* 10 gallons per acre is applied at intervals of one week, beginning when the flies first emerge (about May 15th). About five sprayings are needed; attention should be directed specially to warm and sheltered parts of the field, and the spray should be applied in rather coarse drops, no attempt being made to cover the plants. An

application, as in spraying fruit or potatoes, may cause damage (Ref. 47).

VII.—Animal Pests.

The parasites of farm live-stock are so essentially within the sphere of Veterinary Science that no full discussion of them could properly appear in this article. One or two border line subjects may, however, receive brief mention.

Warble Flies. (*Hypoderma spp.*)

The control of these pests is getting almost beyond the experimental stages, and the work carried out in Worcestershire, North Wales, Scotland, and elsewhere is presumably well known to farmers. The more recent experiments (Ref. 48), both in England and in America, support the conclusion that Derris is the best insecticide to use ; and in America it is found that Derris as a dust (instead of in soap and water) is effective, if application be thorough (Ref. 49).

That the proportion of warbled cattle is still very large is shown by a Scottish report in which it is stated that the percentage of warbled hides in the Edinburgh Market varies per month from 66 per cent. to 80 per cent. (Ref. 50). The extent to which cattle can be treated against warble flies is of course decided by financial considerations, and there can be no doubt that it is a paying proposition with a high-grade dairy herd. As regards store and fat-stock, the gain is less easy to assess, and it may therefore be noted that a report from North Wales suggests that butchers and dealers are willing to pay from 10s. to 20s. more for beasts with no warbles, which of course is in addition to any gain owing to the improved condition of non-warbled beasts (Ref. 51).

Blow Flies.

Work in Australia, where Blow Flies are the most serious pests of sheep, suggests that the best dressing consists of 4 per cent. phenol in shale oil, with the addition of 5 per cent. of either carbon tetrachloride or oil of Chenopodium (Ref. 52). The carbon tetrachloride or oil of Chenopodium may be reduced to 2 per cent. where the dressing is required only as a repellant (*i.e.*, before the sheep has been struck).

House and Stable Flies.

While it is hardly practicable to prevent flies breeding in manure under ordinary farm conditions, circumstances often arise when it is desirable to deal with manure in places near dwelling houses, or where flies are specially objectionable.

The treatment of manure with borax is reasonably satisfactory as regards killing flies, but it renders the manure harmful and, if applied in quantity, destroys the fertility of the soil.

An alternative insecticide which is said to be quite satisfactory and much less harmful to plants, is sodium fluosilicate (Ref. 55). The manure, as it is added to the heap, is sprayed with a solution of sodium fluosilicate (1 part sodium fluosilicate : 154 parts of water). It is stated that up to 300 lb. of sodium fluosilicate per acre can be applied without ill effect on the crops, and as the treated manure would contain but a very small quantity of the chemical, it is clear that it could be applied to the land for years at normal rates without interfering with plant growth.

Lice on Poultry.

The discovery in America that nicotine sulphate can successfully be used against poultry lice is of value, and several papers on the subject have been published. The treatment consists in painting the roosts with nicotine sulphate: it is said that ½ lb. of nicotine sulphate is sufficient for each 100 ft. run of roost, but that no lime should be present (presumably because it would result in too rapid an "evaporation" of nicotine) (Ref. 33). It is also said that a second application is desirable after 9 days, and that "reasonable ventilation" should be given to the house to prevent the fowls from suffering from nicotine poisoning.

It would seem doubtful whether the treatment is effective against fowl mites (red mites, etc.), although a strong nicotine wash (one part nicotine sulphate to fifty parts of water) is found to be a good spray for the interior of houses as a disinfectant against mites (Ref. 54).

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SOILS AND MANURES.

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I.—Soils.

In common with most other organisations, Agricultural Experiment Stations all over the world have suffered during the past year from the financial depression. Grants were curtailed in October 1931 by amounts varying according to the conditions in the different countries. Probably the British research stations suffered least, the cuts here being about 5 per cent., but that was because expenditure had already been thoroughly overhauled and reduced as far as was possible without dismissing staff. Some of the large American Stations suffered much more, the cuts being 28 or 30 per cent.—though others escaped with less. The great tragedy, however, has been in Central and Eastern Europe, where cuts have been so severe as to leave in some cases barely sufficient for gas, electricity and simple materials : the reductions in staff and in the salaries of the survivors are very heavy, and nothing remains for the special equipment without which even the best scientific worker labours in vain. Some of the new countries had begun to do admirable work in agricultural science : Poland, which possesses some gifted investigators ; Czecho-Slovakia, which has developed an active agricultural academy ; Roumania ; Finland, where there is a good group of soil workers : all these countries find their efforts nipped in the bud because of lack of appliances.

The financial crisis has caused the Experiment Stations rather to consolidate work in progress than to break new ground : in consequence there is little that is entirely new to report though much useful work has been done in completing half-finished investigations. The stations are thus clearing the way for fresh activities as soon as the situation changes. In particular, methods are being devised for lowering costs of production, partly by new devices, partly by improving the efficiency of existing methods and appliances.

Several important books on Soils and Fertilisers appeared in 1931 or early 1932. In one of these B. A. Keen (Ref. 1) reviews critically the investigations of recent years on the physical properties of soil and sets out the information yielded by them in a clear concise manner that the student can readily follow.

Dr. A. Demolon, the gifted Director of the Versailles Experiment Station—the leading Station in France—has published a volume (Ref. 2) in which he discusses with characteristic lucidity the changes taking place in the soil.

Sir Frederick Keeble has published—in 1932—an admirable volume (Ref. 3), in which he sets out very attractively the effects of fertilisers on crops, quoting freely from results obtained at

the new station at Jealotts Hill, both on arable and on grass land. He deals with the wider national aspects of crop production and shows how the country could produce much more of its food than it does at present. Viscount Astor and Lord Lymington have also published books dealing with these national aspects (Ref. 4). A new edition (the 6th) of the writer's *Soil Conditions and Plant Growth* was issued by Messrs. Longmans and arrangements made for its translation into German, Spanish, Russian and Ukrainian. A volume was also issued on Artificial Fertilisers (Ref. 5) in 1932: the second edition is now being printed.

A new venture, due mainly to the energy and enterprise of Sir Frederick Keeble, promises to be of great value to agricultural experimenters. Hitherto there has been considerable difficulty in publishing detailed accounts of agricultural experiments. Short accounts of the results always find acceptance in the technical agricultural press, which in this country reaches a high standard of excellence, but the full accounts which the expert requires are not so readily publishable. It is proposed therefore to issue from the Oxford Press a new journal to be called the *Empire Journal of Experimental Agriculture*, to deal with husbandry investigations, field trials, feeding trials and the like. This will overcome many of the troubles of the past and it should be a great factor in promoting agricultural developments. The new journal will thus be the counterpart of the *Journal of Agricultural Science*: there will of course be no overlapping.

Water in Soil: the New Type of Investigations.

In recent years a new kind of soil investigation has been developed: the study of soil management on the field scale. Much of the work has been done in Germany, Sweden and Czecho-Slovakia. No English name for this new subject has been invented, but the German name, used over most of the Continent, is "Kulturtechnik"; it has already an important journal (Ref. 6), many books have been written on it, and there are lectureships on it at several of the larger Universities. Most of the leading "Kulturtechniker" attended the meeting of the VI Commission of the International Society for Soil Science held at Groningen in July 1932.

One of the most important subjects they have set out to investigate has been drainage of field soils, and this has given a new interest and a fresh impetus to the study of the movement of water in soil. I propose to discuss this new work in some detail, as it illustrates very well the way in which laboratory and field investigations are made to discover what is going

on in the soil, and how attempts are made to put this knowledge to some practical use.

It is well known that the first shower of rain falling on the soil after a drought is greedily sucked up, but more continued rain is not, and finally the water is left lying in puddles or waterlogging the soil. The distinction has therefore long been made between the water held tightly by the soil and incapable of movement, called hygroscopic moisture; water held less tightly but not capable of being drained away, called "capillary" water; and the loose-lying water, called "free" or "gravitational" water, because it is free to move and easily drains away. The distinction is very useful agriculturally because while, on the whole, the capillary water is the source of supply to plants, the gravitational water may be harmful to them by asphyxiating their roots. Hence the general aim of cultivation is to increase the capillary water and to remove the gravitational water. The increase in capillary water is brought about by improving the tilth—giving a better crumb structure to the soil—and the removal of the gravitational water is done by drainage.

The Movement of Water in the Soil: the Old-time Capillary Movement.[1]

It was for many years supposed that the capillary water served the useful purpose of keeping the whole mass of the soil moist just as the oil in a lamp keeps the wick moist.

Most men who have been through an agricultural course have been taught about the "capillary" movements of water in soil. We all remember the experiment with the capillary tube, in which water, contrary to expectation, runs *up* the tube without any external aid. This experiment is associated with another in which dry soil is packed into a tube which is then placed in water; thereupon the water begins slowly but steadily to rise through the soil. It goes slowly through a heavy soil, but rises to a considerable height; it goes more quickly through a sandy soil, but does not rise so far. The experiment is simple, and it lends itself to a relatively simple explanation: capillary films are supposed to surround the soil particles and to lift the water from below; so long as the films are intact the lifting can go on, but it ceases as soon as they become broken. The protective effect of a mulch on the soil moisture was explained as the breaking of water films in the surface layer, thereby causing the water to stop its upward rise just below the surface, so that it remained safe from the drying action of the wind.

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[1] Dr. B. A. Keen has given me valuable help in this section.

The whole conception had the merit of simplicity and of general accordance with farmers' practical knowledge. It was further developed in 1897 by Lyman Briggs of the United States Department of Agriculture Bureau of Soils, one of the most ingenious investigators the Bureau ever had. He replaced the idea of water rising up through capillary tubes by another: the idea of water creeping in films over the particles. His papers served the valuable purpose of directing general attention to the problem and of helping teachers to present a difficult subject in an attractive form.

Nevertheless, the underlying idea was not quite sound and the simple straightforward "capillarity" of twenty years ago is no longer held. No expert would now speak confidently about capillary movements of water in soil, except near a water table, and there is no evidence whatsoever for the old "capillary tubes" which were supposed to be broken on mulching.

The first serious blow to the old ideas was dealt by a Dutch investigator J. Versluys (Ref. 7), but his paper did not attract much attention in this country: it was not very clearly written and it came during the War when British agricultural experts were too fully engaged to study it. Versluys showed that the "capillary" water was not at all a simple affair; it was more complex than was supposed on Briggs' water film hypothesis. Meanwhile, in 1921, B. H. Wilsdon, now of the Building Research Station, Watford, but then Agricultural Chemist to the Government of the Punjab, worked out mathematically a representation of the water content of an "ideal" soil, *i.e.* one of perfectly uniform structure and texture: this was a very good piece of work. Dr. Keen, who by this time had returned from military duty to Rothamsted, took up the matter and found a flaw in the theoretical work which led him and his colleague W. B. Haines to re-examine the whole question. A great amount of work by numerous investigators has followed.

The present position is that "capillarity" plays a great part in the holding of water in the soil, but one cannot say what part it plays in the movements of water. The difference from the old view goes right back to the beginning. "Capillarity" in the modern view is related to the pore spaces between the particles: not to the particles themselves, as Briggs supposed—the supposition that led the older investigators astray. But the pore space is a difficult thing for the student to visualise, and the behaviour of water films in pore spaces is still more difficult so that the new work, while much more accurate than the old, is less easy to expound in a lecture.

The complex relationships of pore space and capillary films have been studied in detail by Haines (Ref. 8). He has brought

out the important point that the pore space in soil must be regarded as cells communicating with each other through relatively narrow necks and that, in general, a change of moisture content at any point in the soil proceeds not in a smooth, continuous manner but relatively abruptly, by the sudden emptying or filling of a cell. This type of movement is a joint consequence of the geometry of the pore space and the physical properties of curved water films. Haines has further shown by theoretical reasoning and by experiment that these properties have another important effect: changes in moisture content are not, in the main, strictly reversible, but fall into two series corresponding to the directions of increasing and decreasing moisture content. In other words the curve connecting moisture content with progressive changes in the equilibrium conditions in the curved water film is not a single one but a loop; one branch refers to increasing moisture content, the other to decreasing moisture and the complete cycle is known as the hysteresis loop. The phenomenon of hysteresis is common in physical science: a familiar illustration is the magnetisation of iron. As applied to soil conditions it means that the value of the water content of soil is not unique for a given equilibrium condition, but depends on how the given condition was approached.

A third reason for the change in outlook is the recognition that the soil is not composed entirely of hard, inert particles as Briggs had for simplicity assumed; it includes substances having colloidal properties, one of the most important of which is the power of absorbing water and firmly holding it: the firmness, however, depends on the amount present, small quantities being held much more tenaciously than larger quantities.

These new conceptions, the referring of the water film to the pore space instead of to the particle, and the recognition of colloidal properties and of hysteresis and the many consequences following therefrom, have completely changed the whole idea about capillarity. As a way of holding water up in the soil against loss of gravity capillarity is recognised as a potent force. As a means of moving water about in the soil upwards, sideways, or in any other direction, its operations are so complex owing to the varying shapes of the pore spaces and the influence of the colloidal properties that no one would venture to predict what would happen (Ref. 9).

We are, therefore, driven to direct experiment. In no natural soil yet studied has capillary movement been found to proceed far, or to play any important part in supplying water to the crop or in bringing water to the surface to make good the loss caused by drying out. Careful determinations of the water

content of the soil have shown rapid losses close to the surface, but considerably smaller losses below. Several sets of experiments have shown this. Keen discusses the physical evidence in his book (p. 92): Sen (Ref. 10) in India could trace no capillary movement beyond 2 feet. A simple and convincing demonstration, however, is given recently by Bijl (Ref. 11) who has studied the influence of ground water level on the vegetation in the Dutch Dunes. He showed that the growth of grass was good when the water level was maintained at 12 inches (30 cms.) below the surface, but poor when the level fell to 20 inches (50 ims.) it failed altogether when the fall went further to 24 inches (60 cms.). On arable land the most favourable depth of the ground water was 20 inches (50 cms.): if the depth were 32 inches (80 cms.) crops were uncertain: if it were 40 inches (100 cms.) they failed.

How does the Water Travel?

If water does not move much by capillarity, how does the bulk of it travel? After all we have to account for a good deal of water movement. Of the rain water falling on the surface of bare soil at Rothamsted, about half penetrates the soil and half evaporates: on cropped land, however, the penetration is much less: usually about 25–30 per cent.:—

	Percentage of rainfall percolating through soil.
Hertfordshire (Hemel Hempstead) (Ref. 12)	21·8
Hante-Savoie (Ref. 13)	26
Sweden, various places, average (Ref. 14) .	26
Germany (Ref. 15), N.E. region . .	29
Elbe Basin .	28

Most of this soaks away downwards, or drifts along some impermeable layer till it finds an outlet. In general, it appears that water travels through the pores of sand and silt soils, but down the cracks in clay soils. Evidence of this is afforded by inspection of the face of a fresh cutting, say 4 or 5 feet in depth: the clay is found to break easily into leaves or plates along the face of which are the red or brown stains left by the iron or manganese dissolved in the water; or if the clay is permanently waterlogged the stains are greenish, and they may be so widely spread over the soil that they make it look completely green until one breaks the lump, when its proper brown colour appears.

A demonstration of this movement along cracks or interfaces, was given by two American workers Slater and Byers (Ref. 16). They took a sample of the soil with a wide cylindrical borer, and without disturbing it poured water on the top to saturate it. Then they poured on a solution of a dye which

they allowed to run through. The block of soil was then dissected. The dye stains were found only along the cleavage surfaces and root channels: not throughout the mass of the soil.

The Draining of Soil.[1]

The downward drift of water through the pores of a sand or silt, or through the cracks and interfaces of a clay soil, accounts for the slow movement that occurs in undisturbed soil, but it does not explain how drains act. The usual picture of the drainage process given in the text books is that the water finds its way into the drain from all directions but mostly from above, so that the soil immediately above is fairly dry, while that in the middle between the two drains is wetter. A curve is usually drawn from one drain to the next, rising to a summit mid way between them, to represent the water content of a drained soil. Those who are mathematically inclined can make great play with curves of this kind and some interesting calculations have been made showing the best depth of drains and best distances between them in order to secure efficient drainage most cheaply (Ref. 17).

Experiment has shown, however, that the text book curve is obtainable only under special circumstances; only when there is a definite water table in the soil and the drains are made below this. The water is then carried away and during the process of removal its distribution (or "profile") is as shown by the curve. A sudden temporary rise in the water table—such as is obtained after heavy rain or after a spring thaw—may be drained away in the same manner (Ref. 18).

But these represent the exceptional and transitory, not the ordinary every-day conditions in a drained soil. These have been studied in Sweden in an important investigation by Flodkvist (Ref. 19). The flow of the drains was measured for several years on each of six fields, the soils of which ranged from medium loam to heavy clay. The results did not agree with the idea of the usual curve: after heavy rain outflow from the drain increased rapidly and then, about an hour after the rain had stopped, it began to fall sharply. On the old view it should have continued much longer. Flodkvist's explanation is that the ground immediately above the drain, having been disturbed when the drain was laid, allows water to soak down more readily than the undisturbed soil further away—he proved this by direct experiment. So whatever water comes above

[1] In the preparation of this section I have received much help from Mr. J. L. Russell, School of Agriculture, Cambridge.

the drain easily passes down this disturbed soil, but water further away does not. In Flodkvist's view the usual process of drainage in heavy soils is that rain water penetrates the loose surface soil to a depth about equal to the usual depth of cultivation and is there held up by the impermeable subsoil. It then flows laterally down the slope of the field till it reaches a drain trench down which it can easily find a way. This view needs some modification where the surface soil is impermeable or the subsoil permeable, but it seems to explain the facts better than the old one. Certain experiments at Cambridge on mole draining on a heavy clay indicate that the water gets into the drains through the slits made by the mole plough, rather than by any general percolation (Ref. 20).

An interesting point brought out by the modern drainage work is that the proper function of drainage is not simply to remove excess of water, but to secure a better distribution of water in the soil. In actual fact a drained soil is not infrequently somewhat moister than an undrained one, especially in dry weather. This was brought out by the measurements of Thørgersen in Denmark (Ref. 21). In Siebert's experiments (Ref. 18) he not infrequently found that the soil immediately above the drain was moister than that in between the drains, especially in heavy soils or during dry weather, a result that had already been obtained by Solnar in Czecho-Slovakia (Ref. 22).

The explanation put forward by Mezger (Ref. 23) is that the drain pipe allows the escape of the soil air which otherwise, being imprisoned, would impede the free movement of the rain water. Over the drain, therefore, the water can distribute itself regularly throughout the soil instead of accumulating in one restricted zone.

The Movements of Water Level in Wells.

Closely related to the movements of water in soil are the changes in water level in wells ; it has long been known, of course, that the level in the well is not necessarily identical with the level in the soil. This question has recently been studied in detail by Thal Larsen in Holland (Ref. 24). The first effect of a heavy shower of rain was to cause a rapid rise in water level in the well which was much greater than corresponded with the rainfall. Then the water level quickly fell again. The effect was traced to the air imprisoned in the soil by the heavy shower : this cannot get out and so it presses out the ground water into the well. Before long, however, the entrapped air escapes and so that pressure is released and the level in the well falls.

The "Dead Layer" in Soils of Rather Dry Regions.

In many of the dry regions of the world there is in the soil not very far below the surface a dry layer which the rain water never reaches and through which the ground water never rises: it therefore remains permanently dry or "dead." Plant roots cannot penetrate it, so that they cannot reach the subsoil water: they are therefore dependent on the surface moisture, which is very apt to fail.

This layer has long been recognised in Russia and has been studied by one of their distinguished soil physicists, Doyarenko, whose work on this and other soil problems originally published in Russian has now become available to western readers through the publication of a detailed summary by Krause (Ref. 25). It is attributed to the air in the soil which becomes imprisoned by the rapid rainfall usual in dry regions and so prevents the water from flowing down too far. It is reduced in amount by a cultivated bare fallow carried on for a year: this forms a loose surface layer that easily absorbs the rain and easily allows the air to escape. It is most pronounced, however, when the surface is left compact because this itself holds up the water and tends more effectively to imprison the air.

Land Reclamation.[1]

In spite of the serious plight of agriculture there is still a good deal of land reclamation going on. The largest scheme is the draining of the Zuyder Zee in Holland.

The Draining of the Zuyder Zee. (Ref. 26.)

An account was given in 1929 of the reclamation of the Zuyder Zee, so far as it had then proceeded. The writer revisited the work in July, 1932, and had the opportunity of discussing it with some of the engineers and chemists concerned, notably Dr. D. J. Hissink, President Ir. Smeding, Prof. Visser, Ir. Zuur and others. In spite of the adverse financial conditions the work has continued, and is indeed in advance of the forecast of 1929.

It will be recalled that the scheme does not involve the draining of the whole of the sea called the Zuyder Zee on the English maps, but only the southern part—the true Zuyder Zee. The northern part enclosing the chain of islands and called by the Dutch the Waddensea, is not included. The main dyke extends from north Holland to the Island of Weiringen ($2\frac{1}{2}$ km. $= 1\frac{1}{2}$ miles), then from the east side of the island

[1] Dr. Hissink has kindly read the manuscript of this section.

across to Zürig, south of Harlingen in Friesland (30 km. $=18\frac{1}{2}$ miles). A total length of 20 miles of dyke had thus to be constructed: the work was due for completion in 1934: actually it was finished in May, 1932, though the road and double line of railway which will run over it is not yet completed. This dyke is $7\frac{1}{4}$ metres (24 feet) above mean sea level and 90 metres (295 feet) wide at sea level. Its construction was greatly facilitated by the discovery in and near the Zuyder Zee of a glacial marl, which does not disintegrate in sea water and therefore forms a useful part of the means adopted for protection on the sea side.

The dyke is provided with 25 sluices to allow of the rapid removal of water from the land side. The total cost has been about 125 million guilders (£10 million at par). The great area of water thus enclosed is ultimately to be divided into five parts, four large areas of cultivated land (about 500,000 acres in all) and a large freshwater lake of 100,000 ha. (247,000 acres) to be called the Yssel Lake. Of the new soil some 70 per cent. is heavy loam or clay, 20 per cent. is light loam and 10 per cent. is sand. Quite apart from the new land gained from the sea, the new dyke has several advantages. It keeps out the North Sea and so obviates the floods which have from time to time seriously injured the southern part of the old Zuyder Zee—*e.g.* in 1916, when damage to the extent of 20 million guilders (£1,700,000) was done; also it greatly reduces the cost of maintaining the dykes round the former sea, and of pumping the water out from the low-lying land. The Yssel lake will have a constant level, not the varying level of the old sea. The large supply of fresh water available in the lake will be invaluable to the surrounding low-lying polders: these will no longer suffer, as at present, from the lack of fresh water in summer. These various advantages in themselves outweigh the £10 million spent on the dyke, to say nothing of the convenience of easier access from one part of the country to another. Of the four polders to be formed ultimately, one, the Wieringermeer, has already had the sea water pumped out, though much of it still remains very wet. Its area is 20,000 ha. (50,000 acres). Three operations have now to be done:

(1) setting up of drainage ditches and division of the area into fields and farms;

(2) levelling, cultivating and sowing in readiness for handing over to the cultivator;

(3) colonisation: building of roads, villages, schools, churches, farmhouses, cottages.

The drainage system is exceedingly important. The new

land is 3–4 metres (10–13 feet) below sea level: the annual rainfall is 760 mm. (30 inches) and the evaporation only 400 mm. (16 inches): without an efficient drainage and pumping system the new polder would soon be submerged again. As a study in drainage the system adopted is one of the most wonderful I have ever seen, and one marvels at the amazing skill with which it has been worked out. There are four great drainage canals in addition to a system of canals for cheap transport. These are fed by the boundary ditches ("kavelslooten") and then in turn by the field drains, mostly open ditches cut out mainly by machine—among them Fowler's and Maclaren's giving good accounts of themselves. There is a small amount of pipe or mole draining, but rather by way of experiment. It is being done by great machines of several types; some of them make mole drains and then line the drain with wooden pipes, which are made of wood from long battens dragged into the soil as the work goes on: this is the Visser plough (Ref. 27): another, the Rudolf Sack plough, makes a continuous drain pipe out of a long band of sheet iron, and lays it as the work proceeds: a third, the van Bruin, lays ordinary drain pipes as it proceeds. An interesting experimental machine is constructed like an electric cable layer: it cuts the mole and draws into it an asphalt paper tube which, it is hoped, will keep the drain sufficiently open to allow the escape of the water.

A difficulty with all these machines is that the mole drain does not necessarily have a uniform fall: it is influenced by changes in level of the surface.

The cutting of the drains is done while the soil is still wet and easily penetrated.

The farming unit is 50 acres: when the land is divided into holdings it is expected that for dairy farms 1 or 2 units will suffice, for arable farming 2 or 3: every farm will have easy access to road and canal. Division into holdings, however, cannot come for some time. The soil contains far too much salt to permit of cultivation and this has to be washed out by the rain. As soon as the heavy soil begins to dry a vigorous growth of weeds appears, chiefly salt-loving plants, but these must be kept down by shallow cultivation, otherwise they will impede the ploughing and damage the subsequent crop. Deep cultivation is a disadvantage. As soon as the salt is sufficiently removed these heavy soils can be used either as permanent grass or as arable land, according to circumstances. The sandy soils, on drying, begin to blow away: this is prevented by bringing up clay from below by means of the excavating machine and spreading it on the surface: alternatively by putting straw on the surface or by sowing rye. The salt soon

washes out and the sand is then sown to permanent grass, this being the only permanent way of overcoming the "blowing" trouble. A good deal of the sand can be sown immediately down to grass. Artificial irrigation may be necessary. After some 15 years the sand accumulates sufficient humus to permit of arable cultivation.

All this preliminary work is done by the State. Each year it is proposed to bring into cultivation about 10,000 acres. The first crop is a cereal: usually rye or barley. The work is highly mechanised: it is done with colossal implements: ploughs with 8 shares ploughing 15 acres per day to a depth of 4 inches, harrows 33 feet wide, seed and manure drills 26½ feet wide, sowing 50 to 75 acres per day per machine. Ample provision is made for experimental work to deal with the many problems that arise. There is a large State demonstration farm of some 7,000 acres to test the possibility of making a State farm pay; a drainage experimental farm at Kolbarn, one of the most interesting of its kind, set up by a commission under the direction of Dr. Lovink besides the well-known Andijk farm described in 1929. The soil investigations are under the scientific direction of Dr. D. J. Hissink (Ref. 28).

The Dutch Government, however, is not preparing to farm the land itself. After the preliminary years the land will all be disposed of: one-third will be sold outright; two-thirds will be leased—partly as crown leases, partly as long leases ("Erbpacht").

It takes about two to four years before the salt is removed from the heavy soils. So long as the soil water in the subsoil contains no more than 0·3 to 0·4 per cent. of salt (NaCl)[1] it is possible to obtain excellent crops of cereals, roots and grass. Potatoes and vegetables are less tolerant, and peas and beans still less: one must wait till more salt has gone before they can be grown. The soil quickly becomes infected with micro-organisms: no inoculation was found necessary for leguminous crops at Andijk, though it was needed on the Wieringermeer-polder. It is interesting that in places the lower parts of the soil are acid. As an example:

Depth, cm.	0–7	20–26	26–29	31–34	35–45	60–100
pH.[2]	7·4	3·2	2·1		4·3	7·6

Values as low as pH 1 have been obtained. The explanation is that the iron oxide in the soil and the sulphates in the sea

[1] No more than 3 gms per litre cl. in the soil moisture of the layer 5–20 cm. below the surface.

[2] pH. is a scale for measuring soil acidity. 7 indicates neutrality, lower figures acidity, and the lower the figure the more intense the acidity; higher figures indicate alkalinity.

water became reduced in the days before reclamation, forming ferrous sulphide, and this on oxidation gave rise to ferrous sulphate, which interacted with the calcium carbonate. When all the carbonate is gone, any further ferrous sulphate that may be formed causes the soil to become acid.

Reclamation of Tidal Lands.

Considerable interest is being taken in various parts of the Empire in the possibility of bringing into cultivation coastal lands which are dry at low water but liable to heavy flood at high water: some of these are very fertile.

In Holland there are considerable areas in Groningen which the writer recently had occasion to visit. The early stages of the reclamation proceed by purely natural agencies. The silting up of a shallow muddy region is greatly assisted by the growth of sea grass (*Zostera marina*). On land already out of the sea at low tide though still daily flooded at high water *Salicornia herbacea* (Glass wort) and other plants grow, favouring accumulation of silt and sand till finally the daily flooding ceases and a new type of vegetation arises dominated by *Glyceria maritima*, forming the salt marshes. Very high tides, however, still cover them, but the level continues to rise: characteristic land plants appear, such as *Festuca rubra, Agrostis alba*, along with coast plants, *Plantago maritima, Sperularia* and others, making a humus layer of some 20 cm. (8 inches) in thickness, thus binding the soil together. At this stage it is safe to build a wall round the land, set up the drainage system (this is highly important, and in Holland it is done exceedingly well), and bring the land permanently into cultivation. These newly-won lands are called by the Dutch "Kwelders." Their soils are characterised physically by a high porosity which increases with the clay content because the clay is flocculated by the sea water; and chemically by the fact that the iron oxide is mobile as the result of the oxidations and reductions mentioned above. They are rich in calcium carbonate, but the clay fraction is poorer in exchangeable calcium and richer in exchangeable magnesium and sodium than that of the older soils; in other words it is a sodium-magnesium clay, not a calcium clay.

Once the dyke is erected two changes set in. The salt is washed out from the soil by the rain water, and air penetrates, easily oxidising the iron and decomposing some of the organic matter, forming carbon dioxide. Both drainage and aeration are greatly facilitated by the cracks which soon appear. The removal of the salt destroys the clay crumbs and so causes deterioration of the soil texture: the carbon dioxide, however, brings into solution calcium carbonate which interacts with the clay fraction displacing the sodium and magnesium and giving

a calcium clay, which is flocculated by the calcium carbonate. The soil texture thus improves again, but the position is now a good deal altered: it is no longer the good texture of a sodium-magnesium clay flocculated by sea water and liable to destruction by rain, but the texture of a calcium clay flocculated by calcium carbonate and not easily destroyed by rain. The soil, however, never regains its old porosity: this permanently diminishes, and while a newly-won soil had a porosity of 70 per cent., the older soils have values of 50–55 per cent. only. Shallow ploughing only is permissible in the first years of cultivation.

Moorland Reclamation.

A certain amount of moorland reclamation is also carried out in Groningen. The peat is mainly composed of Sphagnum and *Eriophorum vaginatum.* The first stage is as always the making of canals and ditches as the basis of the drainage system. The later stages are based on the fact that the newly-formed peat of the upper layer is suitable for cultivation, but not for fuel, because it burns too quickly (it is used for tinder or as litter), while the old peat of the lower layers is unsuitable for cultivation because its high content of colloidal matter makes it too retentive of water when wet and very dusty when dry. The process consists therefore in taking away the old underlying peat but retaining the more recent top layer. In the first instance the whole of the peat is removed right down to the sand. The old black peat is taken right away for use as fuel or other purposes, and the top layer is put back again: if as much as 80 cm. or 1 m. can be obtained so much the better. It is then levelled and any pieces of old trees or old turf removed if possible. Then on top of this is put a layer of sand about 8 cm. thick taken out from the ditches. Then the cultivating implements go through to mix this sand with about 4 cm. of the peat. In the old days it was customary to give heavy dressings of town refuse: 20 to 30 tons per acre in the first year with smaller dressings in the second. Now, however, artificials are used exclusively. Potatoes are grown as a first crop and given per acre 11 to 13 cwt. of 26 per cent. potash salt, 6½ to 10 cwt. superphosphate and 6½ to 10 cwt. nitrate of soda, which so far as I know is the world's record for potato manuring.[1] In the second year potatoes are grown again and given the same liberal dressing. Lime is applied only occasionally. The third year crop is oats or rye, undersown with clover, which remains as grazing for the fourth year; then

[1] Per hectare the quantities are: Potash salts (26 per cent. K_2O) 1,400–1,600 kg. Superphosphate 800–1,200 kg. Nitrate of soda 800–1,200 kg.

back again to potatoes. The only difference in the later rotations is that the potatoes, instead of being used for human consumption, are used for making starch. Yields of 14 or 15 tons per acre are expected.

Large areas of peat of this kind occur in Friesland and in Germany, and this method is widely adopted.

Alkali soils in Hungary.

Hungary contains a good deal of alkali land of low value in its virgin state, but capable of considerable improvement. Methods have been worked out by the Hungarian experts and put into practice by the Central Committee of Soil Reclamation organised by the Hungarian Ministry of Agriculture: the details are so interesting to those concerned with alkali soils in the British Empire that the Imperial Soil Bureau asked Prof. A. A. J. de'Sigmond of Budapest to prepare an account; this has now been published (Ref. 29). The soils fall into two main types:

(1) Soils which are infertile because they contain soluble salts: these vary from light sands to medium clays rich in calcium carbonate, but they are underlain by a very impermeable layer: they correspond with the Russian "solonchak" described in the Report for 1929 (Ref. 30). These can be reclaimed by washing out the salts.

(2) Heavier soils, mainly free from soluble salts or calcium carbonate, these having usually been leached out, but containing much sodium in the "absorption complex" —which makes the soil very difficult to cultivate. These soils correspond with the Russian "solonetz" (Ref. 31).

Soils of this second group are reclaimed in three ways:—

(*a*) Checking the upward movement of salts: this is done by reducing evaporation by means of surface cultivations, and also by growing lucerne which dries out the soil and so stops salt movement.

(*b*) Rendering the pan pervious by the use of calcium carbonate, press-lime from sugar factories, gypsum, and farmyard manure which generates carbon dioxide and so helps to bring the calcium carbonate into solution.

(*c*) On one type of soil by bringing up marl from the subsoil and spreading it on the surface.

Many thousand acres have been successfully reclaimed,

a great tribute to the activity and enterprise of the Hungarian people.

Pakihi lands of New Zealand.

In the north part of the South Island is a considerable area of land, formerly quite useless for agriculture: the soil is rich in humus, but underlain by a hard pan, it is a "humus podsol" as described in the 1929 report.[1] The possibility of reclamation was studied by Drs. Easterfield and Rigg of the well known Cawthron Institute, Nelson, and they worked out a simple method that has proved very effective. Burning of the wild vegetation, followed by liberal treatment with lime (not less than 1 ton of slaked lime per acre) and basic slag (5 cwt. per acre), then thorough disc cultivation, was sufficient treatment preliminary to sowing with mixtures of seeds and grasses: no deep ploughing or breaking of the hard layer was necessary (Ref. 32).

Laterites and Lateritic Soils.

In recent years considerable interest has been taken in various parts of the Empire in these remarkable soils. The numerous investigations have now been brought together and summarised by the Imperial Bureau of Soil Science (Ref. 33).

These soils are formed under conditions of high rainfall and high temperature, but the rainfall is the more important. Weathering proceeds differently from the course it usually follows in Great Britain: the oxides of iron, aluminium and magnesium are removed less rapidly than the other bases and the silica, so they tend to accumulate; the iron in various hydrated forms and the alumina as gibbsite (Al_2O_3. $3H_2O$). The result is that the proportion of silica to alumina is lower than in our soils. Chemists therefore define laterites as soils which contain gibbsite and in which the rates of silica to alumina is low. Apparently only basic and intermediate rocks can undergo this particular kind of weathering, not granite or other acid rocks, but little is as yet known of the mechanism and the course of the changes.

The name laterite was borrowed from the geologists: it is rather an unfortunate choice because the geologist does not adopt the chemists' definition just given but described as laterites certain surface deposits which are soft when dug but harden slowly on exposure so that they make good building material. It is probable that the two definitions really deal

[1] P. 124.

with the same thing, but the geologist lays stress on the iron oxide while the chemist attaches more importance to the gibbsite and the mode of formation.

Laterite thus formed may undergo further changes. In low-lying situations with alternations of wet and dry periods the ground water during dry periods moves upwards and brings in alkalis and silicates whereby the laterite becomes resilicated : the gibbsite changes to a secondary kaolin. There results, therefore, a layer of red earth, which may be as much as 50 feet thick, consisting mainly of secondary kaolin and hydrated iron-oxide with some quartz—a composition not very different from that of a non-lateritic soil derived from acid rocks. These soils are called " Lateritic soils " or " Red earths."

These " lateritic soils " may undergo further changes. Under heavy rainfall they lose iron and aluminium oxides and leave a quartzose grey top soil under a rich vegetation cover, merging downwards into almost uniform red earth. The process has been studied in Java, where it is well seen (Ref. 34) : it is a curious combination of temperate and tropical soil-forming processes because it amounts virtually to a podsolisation proceeding downwards in a soil where laterisation has already occurred.

The laterites are usually thin, very porous, non-plastic, therefore less liable to erosion than soils with higher silica-alumina ratios. They lack cohesion ; their water relationships are rather special. The bases having been leached out they lack potash and lime, also available phosphate since their high alumina and iron content gives them great power of absorbing phosphoric acid. Further they are acid : the pH generally lies between 4 and 6. They are therefore poor. They respond, however, to good treatment and manuring, particularly to organic manures or green manuring, and they are easy to cultivate.

The red earths or lateritic soils are deeper and may be more fertile : like the unchanged laterites they are very porous and can be ploughed within a few hours of heavy rain, although in other respects they may resemble clays. In practice they are not always easy to distinguish from the true laterites.

Inoculation of Lucerne.

The demand for cultures of the lucerne organism prepared by Messrs. Allen and Hanbury according to Dr. Thornton's method continues to increase greatly ; indeed the figures suggest that practically all new sown lucerne in this country is now inoculated. This is a wise precaution as experiment shows that the inoculated crop is not only more certain to

survive but is likely to be richer in the valuable proteins (albuminoids) than one which is not inoculated. The area under lucerne had been shrinking, but with the introduction of inoculation the shrinkage becomes less and less and now the area is increasing. The data for England and Wales are :—

	Nos. of cultures sold.	Area sown with inoculated seed. (Estimated from cultures sold.) Acres.	Net gain (+) or loss (—) of crop since preceding year. Acres.
1925 . .	—	—	—10,595
1926 . .	898	629	— 7,045
1927 . .	892	624	— 3,412
1928 . .	1,769	1,238	— 6,459
1929 . .	2,038	1,426	— 1,321
1930 . .	7,256	5,079	+ 3,998
1931 . .	9,036	6,325	+ 6,412
1932 . .	—	—	—

The process was worked out in the Rothamsted laboratories and it was put to practical test as the result of grants from the Research Fund of the Royal Agricultural Society. It is interesting to note that the investigation has already added to the farmer's resources far more than its entire cost. We can safely estimate the net value of lucerne over alternative fodder crops as being at least £1 per acre (allowing for its low cost of production) ; and as the crop once sown stays down for some 3 or 4 years with but little attention and then leaves the soil greatly enriched in fertility, we are probably well within the mark at putting the value of this work to British farmers at at least £10,000 per annum.

A full account of the method, and the best way of ensuring the value of the lucerne crop, has been published by Dr. Thornton and should be in the hands of all progressive farmers (Ref. 35).

Dr. Thornton is now studying the possibility of inoculating clover.

Mechanisation.

The need for reducing the labour bill has compelled many farmers to introduce machinery enabling one man to do the work of two or three, and the result has been a cheapening of production which has enabled them to remain solvent in the midst of falling prices. The change is usually called "Mechanisation." It formed the subject of a well-attended Rothamsted Conference at which several important papers were read (Ref. 36). Here we shall consider only those dealing with the maintenance of soil fertility under mechanisation. In the old system fertility was maintained in several ways : by converting the straw into farmyard manure ; by growing clover once in four years so far as possible ; by folding sheep on roots

or other crops on the ground; by the use of artificials. On a mechanised corn farm there may be few or no live stock: hence there is little or no farmyard manure, not much clover, and no sheep folding. The question was discussed: Can the fertility be kept up by artificials alone?

The details are given in the published report. The broad results of the various experiments show that cereals can be grown almost indefinitely on artificials alone and without farmyard manure provided reasonable care is taken to obtain a good tilth. Potatoes and sugar beet, however, are more easily grown with farmyard manure than without it. Mangolds are best grown with it, though yields of about 25–30 tons per acre can be obtained by artificials alone; swedes also can yield some 15 tons or more per acre with artificials alone, but where the climate allows of higher crops farmyard manure should be given.

Three methods are being tested at Rothamsted for returning the straw to the land:

(1) Conversion into farmyard manure in the usual way. In our experiments, about 25 per cent. of the nitrogen in farmyard manure is recovered by the plant as against about 50 per cent. from artificial fertilisers.

(2) Decomposition by the method developed in the Rothamsted laboratories by H. B. Hutchinson and E. H. Richards and put on a commercial basis by the Adco Syndicate; the straw is treated with the necessary nitrogen compound, phosphate and limestone, to encourage the activity of micro-organisms effecting the decomposition.

(3) Ploughing under, the nitrogen and phosphate needed for the decomposition being given in the form of artificial fertilisers. In the autumn a smaller addition is necessary than in the spring, because the soil already contains some nitrate which, if it were not used by the organisms, would probably be washed away in the winter.

If this method proves feasible in practice it has the advantage of economy in labour, for the corn could simply be stripped and the straw ploughed under while the soil was still warm.

These problems are being studied in the four-course rotation experiment started in 1930 (Ref. 37).

Fallowing.

This is one of the most effective ways of maintaining fertility on heavy soils. Remarkable results are obtained at

Rothamsted which are by no means easy to understand. A plot of ground which had received no manure for 86 years, and had grown wheat every year for 82 years, yielded 6.7 bushels per acre in 1925. It was then fallowed for two years and again sown with wheat; no manure was given, but in spite of this the yield jumped up to 28 bushels per acre.

Part of the benefit is due to the suppression of weeds, which do far more harm to crops than farmers generally realise. Fallowing gives the opportunity of killing many of them, and so the new crop is free from harmful competition. But the benefit of the fallow quickly wears off: at Rothamsted it lasts little more than one year. Part of this fall is due to the rapid return of the weeds. It is not generally realised that fallowing gives weeds a wonderful chance for starting life afresh once they get into the field again. This has been shown at Rothamsted by W. E. Brenchley and K. Warington, who are studying in detail the recolonisation of the cleaned and fallowed Broadbalk field by its old pests. They estimate by a pretty good method the number of live seeds of the different weeds contained in the soil: the results are given in Table I, and they show that some weeds, especially Blackbent, Lady's Mantle and Speedwell, thrive vigorously after the fallow, producing very strong plants which furnish large supplies of seed to restock the soil. The only way to retain the benefit of the fallow is to keep close watch on the returning weeds.

TABLE I (Ref. 38).

BROADBALK WHEAT PLOTS.
EFFECT OF 2 YEARS' FALLOWING.

		Buried Weed Seeds. Millions per acre.[1]			
		Before Fallowing (1925).	After 2 years Fallow (1927).	After 1 year in Crop (1928).	After 3 years in Crop[2] (1930).
Alchemilla arvensis	Lady's Mantle	11·4	3·7	10·0	16·5
Alopecurus agrestis	Blackbent	11·3	0·5	4·8	36·5
Arenaria serpyllifolia	Thyme-leaved Sandwort	0·8	0·75	4·5	3·3
Myosotis arvensis	Forget-me-Not	2·1	0·4	0·7	1·4
Papaver spp.	Poppy	82·6	38·0	34·9	34·4
Stellaria media	Chickweed	0·2	0·03	0·5	1·8
Veronica arvensis	Field Speedwell	6·8	1·5	7·3	22·8
,, hederaefolia	Ivy-leaved Speedwell	2·0	0·8	1·1	2·4
,, buxbaumii	Large Field Speedwell	0·2	0·2	2·0	0·3

EFFECT OF 4 YEARS FALLOWING.

		Buried Weed Seeds. Millions per acre.[1] Before Fallowing (1925).	After[2] 4 years Fallow (1929).	After[2] 1 year in Crop (1930).
Alchemilla arvensis	Lady's Mantle	12·3	1·6	5·3
Alopecurus agrestis	Blackbent	11·3	0·2	3·7
Arenaria serpyllifolia	Thyme-leaved Sandwort	0·9	0·7	0·9
Myosotis arvensis	Forget-me-Not	0·6	0·04	0·1
Papaver spp.	Poppy	112·0	23·3	26·9
Stellaria media	Chickweed	0·3	0·4	1·4
Veronica arvensis	Field Speedwell	6·5	0·6	1·6
,, hederaefolia	Ivy-leaved Speedwell	1·7	0·2	0·4
,, buxbaumii	Large Field Speedwell	0·3	0·3	0·3

II.—MANURES.

GREEN MANURING.

British Conditions.

Green manuring affords a simple method of manuring both heavy and light soils and it requires no livestock; it can be practised on completely mechanised farms. Its advantage in certain conditions has long been recognised, but of late years a number of instances have been recorded where it proved ineffective. The most striking is at Woburn, where, over a series of years, green manuring with tares and with mustard has failed to increase the yield of wheat or of barley. Experiments carried out a few years ago on several other farms with the help of a grant from the Royal Agricultural Society of England also yielded negative results.

There are, however, undoubted successes, and investigations have been made and still are in progress to find the conditions under which green manuring is likely to give useful results. Two of the most important factors are the composition of the plant at the time of ploughing in and the time at which the ploughing is done. If the ratio of carbon to nitrogen in the crop is more than 20, the organisms effecting the decomposition may require more nitrogen than is supplied by the crop, in which case they draw on the soil nitrates that would otherwise either be washed out or taken by the plant. If, however, the ratio is less than 20, the organisms may not need the whole of the nitrogen, they then leave the excess in the soil in the form

[1] Each figure gives the mean of 28 determinations, the aggregate area examined being 7 square feet. One million per acre corresponds with 160 per 7 square feet.

[2] Figures incomplete. Will be higher.

of nitrate, which as before, is either washed out or taken by the plant. Investigations have shown that at Woburn the tares crop failed to increase the growth of wheat because it was ploughed under in autumn and rapidly gave rise to nitrate, which was washed out before the wheat plant was sufficiently developed to assimilate it, and in the following spring the wheat suffered from nitrogen starvation. The mustard during its active growth assimilated nitrate and so saved it from loss, but some nitrate escaped assimilation and was washed out because the crop was too small or the soil was bare. Also after the mustard was ploughed in, some of it probably decomposed too slowly to supply useful quantities of nitrogen to the wheat. The value of nitrogen depends on the time when it is given; when given late to barley it increased only the vegetative tillers, not the ear tillers or the number of fertile grains. It seems clear that the process of green manuring needs to be closely adapted to the soil and the crop so as to ensure liberation of nitrate only when the plant is in a position to take it up (Ref. 39).

Continental and Tropical Conditions.

Green manuring has long been recognised as valuable in the tropics. In some instances the crop is left on the ground, in others it is ploughed in. Six general effects are attributed to it:

(1) Protection of the soil from erosion.

(2) Shading of the soil from the heat of the sun.

(3) The roots of the green crop bore a way through any pan or hard subsoil layer, afterwards roots of the main crop can follow.

(4) Improvement of the texture of the soil.

(5) Conservation of soil moisture.

(6) Fixation of nitrogen.

The experimental evidence, however, is not always convincing: sometimes it is very conflicting. An important summary of the literature has been drawn up by the Staff of the Imperial Bureau of Soil Science (Ref. 40) in which reference is made to 437 published papers scattered widely over many of the agricultural journals of the world. As this publication is easily available to all who are interested it is unnecessary to do more here than indicate some of the general conclusions.

Dealing with the above points in order, there is good evidence of the value of cover crops in checking erosion. A number of plants are quoted as suitable in various parts of the Empire or under various cropping conditions.

The effect of a green manure crop on the moisture content of the soil is more complex. The crop has two opposite effects on the soil moisture. It conserves soil moisture when it shades the soil effectively from the great heat of the sun ; but it also uses up soil moisture because its own leaves are continuously sucking up water from the soil. Sometimes one effect is the greater, sometimes the other : the question whether there is a net gain or a net loss turns on the crop and on the conditions. A number of interesting examples are quoted.

A beneficial effect on the hard pan and the subsoil seems to be established. Deep rooting green manure crops have proved of great value in irrigated regions in breaking up existing hard layers or preventing the formation of a pan, one of the most serious of irrigation troubles.

The effect on soil texture is more difficult to determine because of the lack of means for easy measurement. Sandy soils and light loams seem to show the most definite improvement. Observers in regions as widely different as Lyallpur and New Jersey report a marked improvement in cohesion and water-holding capacity. Heavier loams on the other hand show less regular behaviour : indeed in some experiments an adverse effect was observed, and the manured land did not work down to as friable a seed bed as the unmanured.

There is some evidence that leguminous green manures used regularly over long periods tend to increase soil acidity (or, in other experiments, lime requirement), while non-leguminous green manures tend to decrease it. Instances are quoted where green manuring apparently increased the availability of the mineral constituents of the soil.

Certain seeds—especially those rich in oil, such as cotton and flax—germinate less readily in green manured than in untreated soils, but this is attributed to parasitic fungi, which grow more readily when organic matter is added to the soil. The trouble is avoided by turning in the green plant some weeks before sowing time. Other fungi and also insects are liable to be harboured by the green manuring crop and may damage the main crop. This consideration sometimes rules out crops that would otherwise be desirable as green manure. Against this, however, are numerous records where green manuring apparently decreased the liability of the crop to disease.

Several conditions are necessary to ensure the success of green manuring. One of the most important is adequate rainfall. It has happened repeatedly in dry districts that the crop after being ploughed in could not decompose and so failed to manure the land—indeed moisture was lost by it. On the other hand, the soil must not be waterlogged or decomposition does not proceed normally. Reviewing the whole of the

evidence, it is clear that overseas experimenters have found as many difficulties in green manuring as the British workers. Once the difficulties are overcome the method is effective, but it is not easily reduced to hard and fast rules, and direct experiments need always to be made to assure the development of a successful procedure.

Fertilisers.

The continued fall in acreage of arable land in Great Britain has naturally led to a reduction in the consumption of fertilisers. This has been generally true in most other countries and the agricultural consumption of nitrogen throughout the world fell off from the record of 1·75 million metric tons,[1] (calculated as pure nitrogen) established in 1929–30 to 1·45 million metric tons in 1930–31. An industrial consumption of some 150,000–200,000 metric tons raises the total figures to 1·95 million tons in 1929–30 and 1·62 million metric tons in 1930–31. The nitrogen producing plants of the world have a total producing capacity of about 3 million tons exclusive of Chile, so that they are working at little more than half their full power. All forms of nitrogen fertiliser are affected, but Chile saltpetre more than any other : the only bright spot is that the British share of the trade is increasing ; and in spite of the marked depression, the export of sulphate of ammonia from Great Britain was almost as great in 1930–31 as in the previous year. The home consumption fell off, but no more than corresponded with the fall in value of produce sold off the farm :

ENGLAND AND WALES : 1930–31 COMPARED WITH 1929–30.

	Arable land. Million acres.	Grass land. Million acres.	Value of produce sold off. £ million.			Sulphate Ammonia used.
			Livestock and its products.	Farm crops.	Fruit, Vegs., Flowers.	Thousand tons.
1929–30	9·833	15·547	153·0	37·6	25·5	108·4
1930–31	9·582	15·701	138·7	36·4	21·7	96·3
Fall	·251	·254[2]	14·3	1·2	3·8	12·1

Considering the serious plight of the British farmers, it is very remarkable that they have succeeded in maintaining so high a production.

[1] 1 metric ton = 2204.6 lbs. The figures are quoted from the British Sulphate of Ammonia Federation's Annual Report for 1930–31.

[2] Gain.

Of all nitrogenous fertilisers, sulphate of ammonia still remains the most common is use, though some of the others have gained enormously in recent years as is shown by comparing 1930–31 with 1924–25. Reckoning as pure nitrogen, which is the best basis, the world production in metric tons has been :—

	1924–25.	1930–31.
Sulphate of Ammonia—		
By-Product	278,300	359,594
Synthetic	255,000	349,087
	533,300	708,681
Cyanamide	115,000	200,932
Nitrate of Lime	25,000	110,585
Other forms of Nitrogen[1]—		
Synthetic	66,100	393,150
By-Product	47,400	30,940
Chile Nitrate	367,500	250,000
Total Production	1,154,300	1,694,288

The great development of the nitrogen industry has led to several interesting repercussions. It has profoundly affected the small gas works which used to supply in the aggregate considerable quantities of sulphate of ammonia to the local farmers. The produce was damp, acid, lumpy and often difficult to drill : it was greatly inferior to the fine crystalline powder sent out by the new makers so it has been steadily driven off the market. But the small gas works are still under the necessity of removing the ammonia from the gas, and as they can neither discharge it into the air or the rivers, nor dump it anywhere in any innocuous form, they have no option but to try to sell it. A number of methods have been investigated, but the problem is not yet solved (Ref. 41).

Phosphatic fertilisers.

During the season 1931 there was a big drop in the deliveries of basic slag and a still heavier fall occurred in 1932 : indeed in 1932 the deliveries amounted to less than half those of 1928–9 as shown by the following figures :—

	Total deliveries in thousands of English tons.		
	British.	Imported.	Total.
1928–9 . .	305·9	15·9	321·8
1929–30 . .	295·8	9·9	305·7
1930–31 . .	206·9	8·5	215·3
1931–32 . .	147·2	5·7	152·9

[1] Including ammonia products used for industrial purposes and ammonia in mixed fertilisers.

Until 1931–32 most of this contained 12 to 15 per cent. P_2O_5 (equivalent to 26–33 per cent. tricalcic phosphate) and was of 80 per cent. or more solubility in citric acid. In 1931–32, however, much less of this type of slag was delivered and the poorer slag came more into prominence. The imported slag is mainly of the richer group containing 15¾ to 18½ per cent. P_2O_5 (equivalent to 34–40 per cent. tricalcic phosphate) of 80 per cent. or more solubility in citric acid. The figures are in thousands of English tons :—

	80% or More Soluble.			Less than 80% Soluble.		
	8–11% P_2O_5.	12–15% P_2O_5.	15¾–18½% P_2O_5.	8–11% P_2O_5.	12–15% P_2O_5.	15¾–18½% P_2O_5.
1928–29	82·6	115·0	40·3	15·1	65·4	3·3
1929–30	80·5	108·6	33·2	17·2	56·0	10·2
1930–31	67·2	73·7	11·3	14·9	43·1	4·9
1931–32	58·1	33·4	20·1	5·1	26·5	9·6

The Ministry's Basic Slag Committee's experiments show that the slag of solubility of 80 per cent. or more is better than that of lower solubility so that the improvement in this respect shown by the low grade slags is an advantage. But it is sad that there should have been so drastic a falling off in consumption of the very useful group containing 12–15 per cent. P_2O_5 (26–33 per cent. tricalcic phosphate) of 80 per cent. or more citric acid solubility ; the value of these slags has been proved in many experiments in many places. The smaller falling off in the richer slag (34–40 per cent. tricalcic phosphate) is gratifying so far as it goes ; this group, however, includes all the imported slag.

Since the Basic Slag Committee began its work in 1923, their experiments have consistently shown the superior value of slag of high solubility as compared with that of low solubility. It is interesting and significant to find that the proportion of highly soluble slag offered to farmers has during this period steadily increased and is now far above what it was in 1924 :—

PERCENTAGE OF SLAG HAVING SOLUBILITY OF 80 PER CENT. OR MORE.

1924–5.	1925–6.	1926–7.	1927–8.	1928–9.	1929–30.	1930–31.	1931–32.
51·7	64·6	58·0	66·0	73·9	72·7	70·7	73·0

Mixed Fertilisers.

There is a growing tendency towards the use of the new concentrated mixed fertilisers but some criticisms are already

being heard. In France fears are expressed that the crops or the soil may suffer through the absence of gypsum, which forms half of the ordinary superphosphate, but does not occur in some of the new compounds (Ref. 42). In Germany the criticism is that the new fertilisers do not contain sufficient phosphate but are too heavily loaded with nitrogen and potash (Ref. 43). E. M. Crowther points out (Ref. 44) that these newest and most advanced German mixed fertilisers correspond closely with those adopted by Lawes at Rothamsted in 1856 for the manuring of wheat.

The survey of farming conditions in the Eastern Counties made by the Farm Economics branch of the School of Agriculture (Ref. 45) has brought out the striking fact that many farmers still use no artificial fertilisers. Over the whole set of farms considered, the money expended amounted only to 4*s*. per acre of crops and grass, while nearly 30 per cent. of the farmers bought no fertiliser at all. The small farmers (below 50 acres) and the large ones (over 500 acres) spent about half their fertiliser expenditure on compound manures ; the intermediate farmers (50–500 acres) used more of the separate ingredients and spent only one-third of the total amount on "compounds." The percentages of total expenditure on the farms of different sizes was :—

	20–50 acres.	150–300 acres.	Over 500 acres.	Average cost per ton. £.
Proprietary Mixtures	50·1	32·3	43·9	7·47
Sulphate of Ammonia	15·8	18·3	17·6	9·88
Superphosphate	6·9	10·9	16·6	3·40
Nitrate of Soda	2·9	2·5	4·3	9·82
Basic Slag	1·4	4·9	1·7	2·65
Kainit	1·2	3·2	2·4	3·02
Muriate of Potash	0·1	0·7	1·7	9·28
Lime	0·7	1·7	3·2	1·59
Farmyard Manure	11·6	3·0	1·9	0·29 (5*s*. 9*d*.)

Numerous other fertilisers figure in the list : soot, for example, is purchased to about the same extent as nitrate of soda in all the groups except the farms over 500 acres, on which it is hardly used. The low consumption of fertiliser is of course the result of unfavourable economic conditions. There is clearly in the Eastern Counties a great reserve of food-producing power which is not being used but is lying dormant pending better times.

While the British farmer has been influenced simply by economic motives in deciding the extent to which he would purchase fertiliser there have been one or two movements among continental farmers of quite a different nature. In

Germany a farmer's strike was organised against fertiliser selling organisations in the hope of bringing down prices. This kind of thing is familiar to us all, at any rate in principle, but another movement, also in Germany, lies right outside our experience. A new kind of culture or religion called Anthroposophy has been started by Rudolf Steiner which prescribes among other things the manner in which food shall be grown and especially the kind of fertilisers that shall be given to it. The fact that Neubauer has felt bound to refute the claims of this new doctrine shows that it had attracted a good deal of prominence and might have done some damage to fertiliser interests (Ref. 46).

Farmyard Manure.

Farmyard manure still remains by far the most important manure used on British farms: from the Cambridge enquiry it appears to be used in the Eastern Counties at the rate of 2 tons per arable acre annually, thus applying 24 lb. nitrogen, 10 lb. phosphoric oxide (P_2O) and 24 lb. potash (K_2O) per acre. No fresh investigations have been made in this country, but a number are reported from the continent.

An extensive set of investigations was made in Denmark for a number of years on the fertiliser value of farmyard manure and the results have recently been summarised (Ref. 47). In the Danish experiments the farmyard manure supplied the same quantity of nutrients as the artificials and it proved inferior in action. At Rothamsted the farmyard manure supplied considerably more nitrogen, about 200 lb. to the acre, while the artificials in the ascending series of plots supplied 43, 86 and 129 lb. respectively, and it proved intermediate in average yield between the 86 and the 129 lb., but steadier, the yields being higher in poor years though often lower in good ones. Danish farmyard manure, however, is something different from British farmyard manure. Only the smallest practicable amount of straw is used and the liquid is carefully separated and stored in tanks for direct application to the land. Much importance is attached to the proper storage and use of this liquid manure. If well kept it may contain 0·6 per cent. nitrogen, while if badly stored it may have only half this amount. Fields trials, however, did not always show corresponding differences in effectiveness. It should be added that British samples do not in the writer's experience usually contain more than 0·2–0·3 per cent. of nitrogen, probably because of the admixture of wash water from the stables.

In Germany a new type of manure production devised by Krantz is being tried: the resulting manure is called Edelmist. The process consists in fostering a high temperature fermenta-

tion so that it involves an elaborate covered dungstead; whether the final product justifies the extra cost is not yet established, but the discussion still continues (Ref. 48).

Sewage Sludge.

The old and hitherto unsolved difficulty about drying activated sewage sludge (the best of the sewage sludges tested at Rothamsted) has been discussed by R. D. Anstead (Ref. 49), who suggests that it should be mixed with town waste, whereupon drying would be facilitated. It still remains to be seen, however, whether the fertilising value would remain unimpaired.

Tests of Fertiliser Value.

The severe depression of recent years has made it imperative that the farmer should know as precisely as possible what value to attach to fertilisers and in particular which of two would be the more economical in use. The old method of field experiments does not give this information clearly: there is always an element of doubt about the results and in any case the method is liable to errors of 10 per cent. or more. The modern Rothamsted methods are much better: they are more accurate, they overcome the difficulty about irregularities in the soil; and the value of the final result can be stated either in strict scientific terms or in the more comprehensible odds that the result is really due to the treatment and not to some chance. The method was fully discussed at a Conference at Rothamsted (Ref. 50) at which details were given for carrying out the new experiments in different conditions at experiment stations, on commercial farms, etc. Since then the method has been developed and various additions made to the resources of the experimenter: a formula has been devised (Ref. 51) by use of which the experimenter can still make use of the figures even if one or more of the plots should have been lost through some mischance. This is very liable to happen in places where the staff is inadequate to deal with the whole of the work expected of them.

Unfortunately it has not as yet proved possible to increase the accuracy of working per plot, the error still remains of the size given last year, and experimenters have sought in vain for the better implements that will secure uniform distribution of seed and fertiliser, the chief source of the trouble. Most implements give very rough distribution; the best seed drill for uniform delivery is one made in Czecho-Slovakia and the best fertiliser drill is one made in England, but neither is yet as good as the experimenter would like to have.

This question of accurate implements for agricultural

experiments is very urgent. Much time and money are spent on field trials, but much better results could be obtained if better implements were available.

Methods of estimating fertiliser requirements of soils.

Chemical analysis of soil has long been practised in this country though it has rather fallen into disuse in late years owing to the difficulties of interpreting the results. On the continent two plant growth methods are used and a third has recently been put forward. The methods of Mitscherlich and Neubauer are described in last year's Report (p. 176); a summary of the extensive literature has now been prepared by R. Stewart and issued by the Imperial Bureau of Soil Science Ref. 52). All the various methods can be criticised on theoretical grounds: they would, however, still serve a useful purpose if they gave results that accorded with practical experience. An extensive field test was made in Saxony by Roemer and his colleagues (Ref. 53): in 720 field experiments the Neubauer method gave 73 per cent. right answers for phosphate and 64 per cent. for potash: it gave 22 per cent. wrong answers for phosphate and 33 wrong answers for potash. In another extensive set of field trials Rathsack (Ref. 54) obtained for potash 63 per cent. agreement for the Neubauer and 86 per cent. agreement for the Mitscherlich methods. The difficulty about all these figures is the lack of knowledge of the experimental error in the field trials: until we have better field results it is impossible to pronounce definitely on the values of the different methods of assessing manurial requirements.

Meanwhile the chemists are still working at the chemical methods, especially for phosphate determinations. Hibbard in California (Ref. 55) finds that better results are given by the ratio of the amounts of phosphoric acid extracted under two different conditions than by the absolute amount extracted by any one solvent. Soils needed no phosphatic fertiliser if the phosphate extracted from them by 0·001 N hydrochloric acid was 60 per cent. or more of that extracted by 0·05 N acid; and if the 0·001 N acid extracted 300 or more parts of PO_4 per million of dry soil. If, however, the ratio was 50 per cent. or less, phosphatic manuring became necessary.

Other chemists have continued work on the use of water or carbonic acid as a solvent for soil phosphoric acid, but the question still remains under discussion (Ref. 56).

For potassium a new method has been devised by H. Niklas and his colleagues at Weihanstephan, in Bavaria (Ref. 57). The soil to be tested is used as the basis of a culture solution in which the fungus *Aspergillus niger* is grown. All elements needed for the nutrition of the fungus are supplied

artificially excepting only potassium, which it has to extract from the soil. The amount it succeeds in extracting is easily determined, and is used as a measure of the amount which the plant could extract. Further experience must accumulate before a final opinion can be given as to the value of this method.

Elements Needed by Plants only in Small Quantities.

Plants are made up of some nine or ten elements in rather large amounts ; of these carbon, hydrogen and oxygen come from the air and water, and are not usually under control in this country ; nitrogen, potassium, calcium and phosphorus come from the soil and are regularly controlled by the use of artificial fertilisers ; magnesium, sulphur and iron occur in some of the fertilisers, and are, therefore, supplied incidentally ; in any case they are usually present in sufficient amount in the soil.

Besides these, however, there are other elements needed only in very small amounts. How many of these there may be is not yet known. The most detailed studies have been with boron, the necessity for which has been demonstrated by K. Warington in the Rothamsted laboratories. Miss Warington finds that plants without boron neither grow nor flower normally—special symptoms are produced, including death of the apices and breakdown of conducting tissues. These effects appear much more rapidly in summer than in spring or autumn. The difference is not in the temperature but in the hours of daylight, since plants grown without boron in summer but allowed only 9 hours of daylight are also slow to develop the symptoms, and behave, indeed, like plants grown in spring.

There is some superficial resemblance between the effects of light and of boron. Plants supplied with boron, but allowed only a short period of light every day, fail to develop flowers just as if they were deprived of boron ; but they will produce flowers when they are given more light, while those without boron will not.

The amount of boron needed by plants is exceedingly small. Of all plants yet tested, broad beans seem to require most, but even for them access to 0·2 mgms., and probably less, of boric acid (H_3BO_3) per week per plant during the growing season suffices, while peas and barley require much less. Apparently all plants require some.

These very small amounts are usually, if not invariably, present in the soil. No clear case is known where addition of boron has improved plant growth in the field. There are a few possible exceptions which deserve further investigation :

e.g. a certain tobacco disease in Java may be attributed to boron deficiency.

When the need of the plant is satisfied, further quantities of boron may easily do much harm ; citrus growers in California have suffered loss through the presence of boron in the irrigation water. Manuring with boric acid is certainly not recommended ; indeed, it is strongly to be deprecated.

Manuring of Sugar Beet.

The experiments on the manuring of sugar beet have not yet shown how to raise the yield of this crop to the extent that might reasonably have been expected. A new series of experiments has been started at Rothamsted and elsewhere which it is hoped will provide valuable information in which different varieties and fertilisers are worked into the same experiment. It is unfortunate that no provision was made for research into the nutrition and cultivation of sugar beet when the subsidy was set up : in consequence only little systematic work has been done and we know less about it than about almost any other British crop. The average yield of 7 to 9 tons per acre is inadequate as the basis of a permanent industry, yet until the crop is better understood we are not likely to improve upon it. When the cultivation of the crop was started in this country two assumptions were made, both of which are now known to be wrong :

(1) That the sugar beet, being botanically allied to the mangold, should be manured and cultivated in the same way ;
(2) That the methods successfully evolved by the research workers in Central Europe could be applied here with equally good results.

It is not yet too late to start a well-planned investigation into the manuring and varieties of sugar beet ; but it would have to continue for a period of years on sound lines with the single purpose of discovering how the plant grows and how it feeds. Without this knowledge we cannot expect to raise the yields from their present low levels.

Barley.

The experiments carried out at Rothamsted and elsewhere under the Institute of Brewing Research Scheme have shown how to combine good quality with good yields, and the results have been repeatedly placed before farmers so that they have become widely known. The Institute's experiments began in 1921 and have continued ever since. It is a striking and interesting fact that yields which had been steady for many

years began to rise soon after the Reports started to circulate among the agricultural advisors and they went on rising till the depression and disappointment of 1930 and 1931 caused farmers to reduce all round their scale of operations. The figures are :—

YIELDS OF BARLEY, CWT. PER ACRE, ENGLAND AND WALES.

1885–89	15·6	1920	14·7
1890–94	15·9	1921	14·3
1895–99	15·9	1922	14·0
1900–04	15·2	1923	14·6
1905–09	16·5	1924	15·4
1910–14	15·3	1925	15·3
1915–19	14·6	1926	16·0
1920–24	14·6	1927	16·4
1925–29	16·5	1928	17·2
		1929	17·8
		1930	14·4
		1931	15·0

The connection with the propaganda and advice arising out of the Institute's work can hardly be accidental, for no other crop shows a rise like this. Wheat, beans, peas, potatoes, turnips, hay, have fluctuated irregularly in yield over this period, being sometimes up and sometimes down, but with no sign of any regular movements. Oats come nearest to a regular upward trend, but this is not so well marked as with barley : and further, the manuring recommended for barley could naturally and properly be used for oats as well.

A new type of experiment on barley has recently been carried out at Rothamsted : a combination of fertiliser and variety trial to discover whether different varieties respond in the same general way to fertilisers or not.

III.—Grassland.

The terrible financial plight into which farmers have been driven has compelled them to devote increasing attention to grassland. For many of them this seems the only hope of bringing down costs of production. Many experiments on grassland are therefore being made at Rothamsted, Cambridge, Aberystwyth, Jealotts Hill, The Rowett Institute and elsewhere, and cheaper and better methods of handling it are being worked out.

Laying down to Grass.

The Rothamsted experiments (Ref. 58) show that the soil conditions and the management play the chief part in determining the final composition of the herbage, but the seeding

determines the profits in the first few years. Various mixtures were sown in various ways in 1928, then all were put under similar management: good grazing with a sufficient head of mixed livestock. At first the herbage on each of the different areas had its characteristic appearance; usually it covered only about 70 per cent. of the ground, the remaining 30 per cent. being bare space. Then the plants that were specially favoured by the conditions began to spread, filling up the bare space and crowding out the unfavoured plants. By 1932 the herbage on the six test plots of Sawyer's field had become fairly uniform in spite of the wide differences in the original seeding. Ryegrass (*Lolium*) and wild white clover form about 70 or 80 per cent. of the whole, the rest is chiefly cocksfoot (*Dactylis glomerata*), which forms 15 to 20 per cent. on all plots though the original seeding of 5 to 10 lb. per acre had corresponded to a variation of 15 to 40 per cent. of the number of seeds sown. Timothy constitutes about 5 per cent. of the herbage and red clover about the same or a little more. The bare space is reduced to 5 per cent. or less. We thus account for some 95 per cent. of the whole herbage.

Broadly speaking, it may be said that the better the land the simpler is the final mixture of plants, and in drawing up a recipe for a seeds mixture one can take as basis the botanical analysis of a good local pasture such as one would like to have, always supposing the soil conditions are not too widely dissimilar. That will ensure a fairly rapid establishment of the final herbage. One can, however, add other plants with the hope of getting some further benefit during the first two or three years, but at the risk that if these do not yield their profit during that time they will probably never pay for themselves at all.

Some interesting studies of this competition between grassland plants have been made at Rothamsted. The experiments show that Italian ryegrass reduces the growth of perennial ryegrass mixed with it, perennial ryegrass reduces the growth of cocksfoot, cocksfoot reduces the growth of timothy, and timothy reduces the growth of rough-stalked meadow grass; in Clapham's phrase the grasses acted as "aggressors" in this order. The order varied somewhat with season; in another year timothy was more "aggressive" than cocksfoot. D. J. Watson has extended the observations by introducing clover (late-flowering red) and varying the manurial treatments. He finds that the heaviest yield per unit area is obtained by seeding with rye grass and giving a complete manure; if, however, alternate plants of rye grass are replaced by cocksfoot or by clover, the remaining rye grass plants grow much bigger, though the other plants grow much smaller than if they were alone and the total

weight of all the herbage per unit area is reduced. In other words, a plant of rye grass suffers less from the competition of a plant of cocksfoot or clover (Montgomery late-flowering red) than it does from the competition of another plant of rye grass. The effect of omitting phosphate from the manuring, however, is to cut down the aggressiveness of the grasses considerably, leaving the clover freer to develop; the omission of potash from the manuring proved a greater handicap to the clover.

TABLE II.

MEAN YIELD OF DRY MATTER IN GRMS. PER SQUARE FOOT.

Seedings.	Manurial treatments.				
	Complete Manure.	No Nitrogen.	No Phosphate.	No Potash.	No Manure.
Ryegrass	68·8	40·3	46·4	45·1	39·2
Cocksfoot	46·4	46·9	33·4	39·0	23·7
Clover	38·6	34·1	30·3	25·6	24·6
Ryegrass and Cocksfoot	52·7	62·8	45·5	65·1	37·0
Ryegrass and Clover	62·2	43·3	31·1	43·6	37·7
Cocksfoot and Clover	41·3	36·9	29·8	48·2	30·8

In the experiments just described the plants were allowed to complete their growth; they were neither grazed nor mown. This same order of aggressiveness, however, is indicated by the final state of the herbage in the different fields at Rothamsted: rye grass, the most aggressive, dominates the rest; among the grasses cocksfoot comes next; then timothy and the others come a long way after or not at all. In other circumstances other grasses, Yorkshire fog, agrostis, sheeps' fescue, become more aggressive and may dominate the herbage.

Management of Established Grass.

From the farmer's point of view the herbage of a grass field may be divided into three groups:

(1) The clovers.

(2) The good grasses.

(3) The undesirable herbage.

In dealing with the herbage there are two golden rules:

(1) The young herbage is most nutritious, and therefore the grass must be kept well eaten down so as to ensure a regular supply of new shoots. This treatment has the further advantage that it reduces the difference between the good and the poor grasses.

(2) Clovers develop best when the grass is prevented from growing too high.

So marked an improvement in pasture land can be obtained by proper grazing and management that many people stop at that and do no more.

Adequate manuring, however, can almost always effect further improvement in the character of the herbage and the amount of young growth. There are two kinds of manuring which produce very different results.

(1) *Phosphatic manuring.* This is the older method, and is usually practised by giving dressings of basic slag. It has the advantage of developing the clover, but in order to gain the full benefit good close grazing is absolutely necessary.

(2) *Nitrogenous manuring.* This method has been brought to the fore by the activities of the agricultural staff of Imperial Chemical Industries : it consists of giving one or more dressings of sulphate of ammonia along with the necessary potash, phosphate and lime and so encouraging an ample growth of grass. As with the phosphatic manuring, close grazing is essential.

The advantage of a clover herbage is that it is very nutritious, rich in protein, very digestible and well adapted to growing animals (Ref. 59) and milch cows. The disadvantages are that it starts later in the season and frequently does not give much keep till the summer. The advantage of grass on the other hand is that it can be made to come very early by dressings of a nitrogenous fertiliser and, by a second dressing, to come late as well.

Several attempts have been made to combine the advantages of both methods (Ref. 60) :

(*a*) *The intensive grazing* method developed in Germany during the war and often associated with the name of Prof. Warmbold (Ref. 61). Perhaps the best known trials in this country are those on Mr. W. Brunton's farm at Tollesby, near Stockton-on-Tees.

This method involves the setting up of a number of paddocks, each provided with water and each manured at least twice during the grazing season. It has the disadvantage of requiring some considerable financial outlay, and in a dry season the expected growth of the grass may not appear.

(*b*) *Strip Grazing.* This needs no special fencing or watering and is therefore less costly than the intensive method. It requires two fields and some ingenuity. To quote Keeble's illustration : one field may be dressed with

fertiliser to give early grass. A strip at one end of the other field is dressed later, so as to give its grass 10 days later. The cattle are put on to this as soon as they have finished in the first field. Meanwhile part of the first field is redressed with nitrogen : the animals return to it as soon as the grass is ready. By adjusting the sizes of the dressed acres to the grazing needs it is possible to obtain full use of the land and the fertiliser.

(c) *Rotation Grazing.* This is being studied at Jealotts Hill, the vegetation side of the work being done by Mr. Martin Jones. A four-year scheme is as follows :

1st year. Early Bite. In the preceding winter the field has been dressed with phosphate and potash ; in February or March with nitrogen ; grazing can begin in late March or April. It is grazed hard through the season so that the grass may be kept down and the clovers can develop.

2nd year. The grass having been eaten down hard, the field gives much less keep in the early season. It is, however, still grazed hard and the clover develops considerably, giving a considerable amount of keep in July and August but little in autumn.

3rd year. Clover now predominates so that there is little grazing to be had before May. There is plenty of summer keep, but the herbage is not too heavily grazed so that the grasses can reassert themselves and provide good autumn grazing.

4th year. There is no spring grazing ; the land is laid in for hay. The aftermath is grazed to the end of August, but not later. The field is then rested and manured to start the new rotation with the " early bite."

It remains to be seen how far a rotation of this sort could be carried out in practice or whether it would be much disturbed by weather conditions.

Manuring of Grass Land.

Nitrogenous Manuring. A number of experiments on the nitrogenous manuring of grass land have been made at Rothamsted. Early spring dressings are more effective than those made in autumn, and the nitrogen increases the growth of grass but depresses the growth of clover. This holds for all forms of nitrogenous manure so far studied, and also for mixtures of cereals with leguminous plants such as are used for fodder mixtures. On the grassland the increased growth is obtained chiefly in spring ; in summer and autumn the

increase is less, or it may even vanish.[1] The effect of reducing the leguminous plants is to cut down the protein content of the whole herbage so that the net gain of nitrogen by the whole crop is only small. Non-leguminous crops usually recover 50 per cent. or more of the nitrogen added in the manure, and the recovery is increased by giving a complete fertiliser ; grassland herbage, on the other hand, shows a much smaller recovery—on the Park grass hay plots at Rothamsted our highest figure is 37 per cent. when sulphate of ammonia only was given ; the recovery is decreased by using complete fertilisers, it may then fall as low as 14 per cent.

RECOVERY OF ADDED NITROGEN IN THE HAY.

ROTHAMSTED PARK GRASS FIRST 18 YEARS.[2]

Source of Nitrogen.	Other manures.	
	None.	Phosphate and Potash.
Sulphate of Ammonia . .	37	20
Nitrate of Soda . . .	35	14

For fodder mixtures the recovery was even less ; in some experiments (Ref. 62) it was even nil.

For non-leguminous crops grown singly the results are quite different. The recovery of nitrogen is usually about 50 per cent. :

Cereals . . .	40–50%
Mangolds . .	60–70%
Potatoes . .	50–70% (Ref. 63)

A further difference is that the recovery is improved by adding potassic and phosphatic fertilisers as well.

We may conclude that when nitrogenous fertilisers are dear they are not very suitable for grazing land unless special precautions are taken to keep the grass young and leafy by frequent and intense rotational grazing. Otherwise the small amount of nitrogen recovered and the depressing effect on the clover are serious disadvantages.

The increase in amount of early growth brought about by nitrogenous fertilisers has the great advantage that it enables the spring grazing to start earlier than would otherwise be possible, and this may often be a great convenience, especially if supplies of roots, silage or other succulent foods have given

[1] Summer manuring has not yet been studied.

[2] In this period complications due to change in reaction were not serious.

out—as not infrequently happens. When nitrogenous fertilisers are as cheap as at present they may advantageously be used for accelerating the early grazing whenever this is needed.

Effects of Phosphatic Manures (Ref. 64). Phosphates, unlike the nitrogenous fertilisers, increase the proportion of clover in the herbage, and so add greatly to its nitrogen or protein content. This increase is not confined to the spring months, as happens with nitrogenous fertilisers ; it is maintained throughout the season, and is continued in the next. The gain in protein may be considerable, much greater than the gain in dry matter ; superphosphate gave the following increases in the first year in grass laid in for hay :

	Percentage gain in—		
	Dry matter.	Protein.	Phosphoric Oxide P_2O_5.
Braintree (1930) . .	42	102	97
Northallerton (1931) .	47	78	195

These results depend entirely on the solubility of the phosphate. In the first year after application water soluble phosphate is most effective, so that superphosphate comes out best ; citric soluble phosphate comes next, hence high soluble basic slag is second ; mineral phosphate and low soluble basic slag are less effective. The value of mineral phosphate as compared with the others changes a good deal according to soil and season. In the drier conditions of Hertfordshire and the Eastern Counties it came a long way behind high soluble slag and was very similar to low soluble slag ; in the moister, warmer conditions of Devonshire it acted more like high soluble slag and was much superior to the low soluble slag.

In the second year the high soluble basic slag did better than superphosphate at several of the centres, both on the hay land and on the grass repeatedly mown, though it has not yet caught up with superphosphate. At the Devonshire centre mineral phosphate acted as well as high soluble slag though it is still behind on the two years' programme, but the low soluble slag showed no sign of improvement.

The experiment is being continued to see what happens in the third and fourth years.

Soluble phosphate (both water soluble and citric soluble) increase the amount of phosphoric oxide (P_2O_5) in the herbage by some 50 or 60 per cent. ; sometimes as at Northallerton by much more ; and of course this improves its value for forming bone and building up the animal's frame. The amounts

involved are, however, only small, and in none of these experiments has much of the added phosphate been recovered in the herbage ; at two of the centres the results have been :

PERCENTAGE OF ADDED P_2O_5 RECOVERED IN REPEATEDLY MOWN HERBAGE.

	Mineral Phosphate.	Low soluble Slag.	High soluble Slag.	Super.
Dartington, 1st year .	4			
,, 2nd ,, .	12		11	
,, both years .	16		19	
Much Hadham, 1st year	3		14	

Here, again, the difference between low soluble and high soluble slags is well shown.

Low soluble slag has given poor results in practically all of our experiments, especially in the South-Eastern Counties. It is said to be more effective in acid soils in Scotland and in the North of England, and this, if true, might be attributed as much to the lime as to the phosphate. Precise comparisons are difficult to make, but the lime value of slag approaches that of an equal amount of ground limestone. There may also be an advantage in supplying lime and phosphate together ; at any rate, on some acid soils phosphates rapidly lose their availability as the result of chemical reactions in the soil.

Composition of the Herbage.

The chemical aspects of the work done during the year have been well summarised by E. M. Crowther in his Report on the progress of Applied Chemistry (Ref. 65).

H. E. Woodman and his colleagues (Ref. 66) have completed a comprehensive experiment in which they compare the composition of the herbage cut at intervals of 1, 2, 3 and 4 weeks during the growing season. During April and May the composition was much the same after 4 weeks as after 1 week's growth, but during the flush period the 1 week growth contained more "crude protein" and less "crude fibre" than the 4 weeks' growth. During drought the vegetation lignified and lost much feeding value. The composition of the herbage was not in these experiments altered by intensive manuring. During summer the nutrient ratio is too wide to satisfy the requirements of heavy milking cows : hence the grass needs supplementing.

H. E. Woodman and R. E. Evans (Ref. 67) showed that the failure of sheep to thrive on pastures deficient in phosphate

and lime is due to lack of these necessary minerals in the food, and not to lack of palatability or digestibility.

A series of papers published from the Research Station of Imperial Chemical Industries at Jealotts Hill shows the effect of intensive manuring on the composition of the herbage on grassland (Ref. 68). In the main the analyses of herbage with 3–5 weeks grazing intervals agree with those of Woodman (Table III).

Table III.

A COMPARISON OF AVERAGE SEASONAL CHEMICAL COMPOSITION DATA; CAMBRIDGE AND JEALOTTS HILL (INTENSIVE SYSTEM) INVESTIGATIONS.

(On basis of dry matter.)

	Cambridge (Ref. 69).				Jealotts Hill (Intensive System) (Ref. 70).[2]				
	3-w ithot	Mont y cut ithout rtili	1930. Monthly ithout fert	Mo with	Tolle tensiv	T m. te locl		29. ts H Pad	Toll arm, inte Padd
Crude protein	21·14	20·23	19·16	19·35	22·6	25·3	23·1	18·0	22·6
Ether Extract	6·04	6·51	3·99	4·14	6·5	7·6	6·3	3·8	7·0
Fibre .	17·16	16·92	20·67	21·20	17·5	19·3	20·5	21·2	19·0
Nitrogen-free extractives .		47·58	47·79	46·27		37·1	40·1	46·6	41·3
Ash . .	7·26(	7·04[3]	6·67[3]	7·32[3]		10·7	10·0	10·4	10·1
Lime (CaO)	1·49	1·67	1·41	1·31		0·80	0·84	0·81	0·81
Phosphoric acid (P_2O_5)	1·09	0·98	1·07	1·07		0·83	0·80	0·56	0·77
Ratio, $\frac{\text{True Protein}}{\text{Crude Protein}}$	0·88	0·89	0·89	0·91	0·87	0·89	0·90	0·81	0·88

The percentage of protein and of phosphorus fell, and that of fibre increased during drought. The protein content was decidedly above the average value for pastures. Generally speaking, the nitrogen and the phosphorus contents of the herbage were closely related.

Studies were also made of the best way of utilising surplus grass. Artificially dried grass was very digestible and superior to good hay. Tower silage, though made with little loss and highly nutritive, was slightly lower in starch equivalent and much lower in digestible true protein than artificially dried grass.

The recent Aberystwyth work has been summarised by T. W. Fagan (Ref. 71). In one paper he discusses the influence of different types of grassland management on the chemical

[1] Not determined.

[2] Pastures grazed usually at three to five weeks' stage of growth.

[3] Silica free ash.

composition and nutritive value of individual herbage plants. In the other papers he deals with the rapid change in composition as grass passes from the pasture to the hay stage of growth, the deterioration once the hay has passed the proper haymaking stage and the deterioration of "foggage" as winter advances. The recovery of added nitrogen differed according to the conditions. On lowland pastures rich in clovers the recovery was, as at Rothamsted, low, indeed on occasions the manured herbage contained less nitrogen than the unmanured, because of the suppression of clover by the fertiliser. On mossy upland pastures on soil rich in organic matter the recovery was high and on some of grassland grazed intermittently by sheep the nitrogen recovered was even greater than that in the manure. T. W. Fagan and H. T. Watkins (Ref. 72) further show that added nitrogen tends to raise the protein and depress the phosphorus content of the herbage: calcium carbonate (added in nitrochalk) has but little effect except when clover is absent and then it raises the calcium content. Phosphate increases the phosphorus content and, when it increases the clover, the nitrogen also. Kainit increases the potassium and the chlorine content.

Further results of the same kind have been published by the Pasture Sub-Committee of the Advisory Committee on Agricultural Science (Ref. 73). Heavy manuring with artificial manures increased the yields and increased also the percentages of the various fertiliser constituents in the herbage.

These results have now been obtained so frequently during the past 50 years that one may take them as established. They were clearly demonstrated in the classical experiments of Lawes and Gilbert at Rothamsted, and the numerous repetitions of subsequent workers have shown how accurate and how complete were the data they obtained and the conclusion they drew therefrom.

Stapledon (Ref. 74) has published some striking figures showing the poverty of the vegetation of hill grazings as compared with lowland pastures:

	Nardus Pasture.	Molinia Pasture.	Fescue Agrostis Open Hill.	Fescue Agrostis Enclosed Hill.	Lowland Pasture.
P_2O_5 .	0·37	0·42	0·35	0·44	0·69
CaO .	0·18	0·23	0·44	0·39	0·85
Cl . .	0·30	0·35	0·47	0·46	0·55
K_2O .	1·66	1·58	2·21	2·10	2·94
N . .	2·07	2·78	2·07	2·60	3·11
Ash . .	2·85	3·34	4·40	3·26	5·82

Wild white clover is one of the great contributors of lime, containing in the dry matter of its leaf nearly 3 per cent. as against only about 0·4–0·6 per cent. in the dry matter of grass.

New Zealand Pasture Investigations.

It is interesting to compare the British results with those obtained in New Zealand. At an important conference held at Palmerston North in August 1931 (Ref. 75) a series of papers was read by some of the leading experts, H. E. Annett, A. W. Hudson, T. Rigg, M. J. Scott, and others, bringing together the results of investigations and practical experience up to date.

Rotational grazing has long been an important feature in New Zealand practice : the best results are obtained by shortening both the grazing and the resting period :

	Butter fat, per acre.
District average	120 lbs.
Ordinary rotation grazing . .	159 ,,
Short period grazing and resting (2 days grazing, 7 days resting) . .	216 ,,

The usual fertiliser is superphosphate : many of the best dairy farmers in the Waikato and Taranaki use this at the rate of 6 to 7 cwt. per acre per annum, which seems an extraordinarily high dressing to our English minds ; but the farms are small and heavily stocked, the grass grows almost continuously and the animals are out on it, getting little else, practically all the year so that heavy fertilising is necessary. Basic slag is used and also nitrogenous fertiliser, to which many of the pastures respond. On the other hand, neither potash nor lime is usually so effective as phosphate. Responses to lime are, however, common in the South Island and in the Canterbury district the response was obtained in all the trials, lime and superphosphate together giving admirable results. The usual methods of determining lime requirement in soils need careful interpretation, for low values which would in England indicate lime deficiency are often obtained on soils which do not respond to lime.

The effect of manuring and other conditions of growth on the chemical composition of the herbage is studied at the Cawthron Institute. The best pastures were found to contain the highest percentage of mineral matter. The herbage is chiefly perennial rye grass and white clover, but the protein content is higher than in England—in one case it was 36 per cent. of the dry matter—while the phosphoric acid content was much higher than that of lime while usually in Great Britain it is less :

AVERAGE MINERAL CONTENT OF INTENSIVE PASTURE, CULTIVATED PASTURE IN GREAT BRITAIN AND NEW ZEALAND PASTURE.

	Great Britain Intensive Pasture (Ref. 76).	Great Britain Cultivated Pasture (Ref. 77).	New Zealand Good Nelson Pasture (Ref. 78).
Lime (CaO) . . .	0·82	1·10	0·83
Phosphoric Acid (P_2O_5) .	0·82	0·77	1·06
Potash (K_2O) . .	3·80	2·97	3·96

Drought, however, lowers both nitrogen and phosphorus content of the herbage besides reducing yield. Other results agree entirely with those obtained at Rothamsted. Phosphatic manuring increased the phosphate content of the herbage. Nitrogenous manuring increased its nitrogen content except during drought; it lowered the lime content, presumably as the result of depressing the clover.

Two kinds of deficiency disease occur in New Zealand. "Bush sickness" is due to lack of iron; it is curable by giving iron licks; limonite and salt in equal weights proved both economical and effective (Ref. 79). "Waihi" disease is due to phosphate deficiency. Sheep suffered from xanthin calculi in their kidneys when kept on very poor pasture.

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